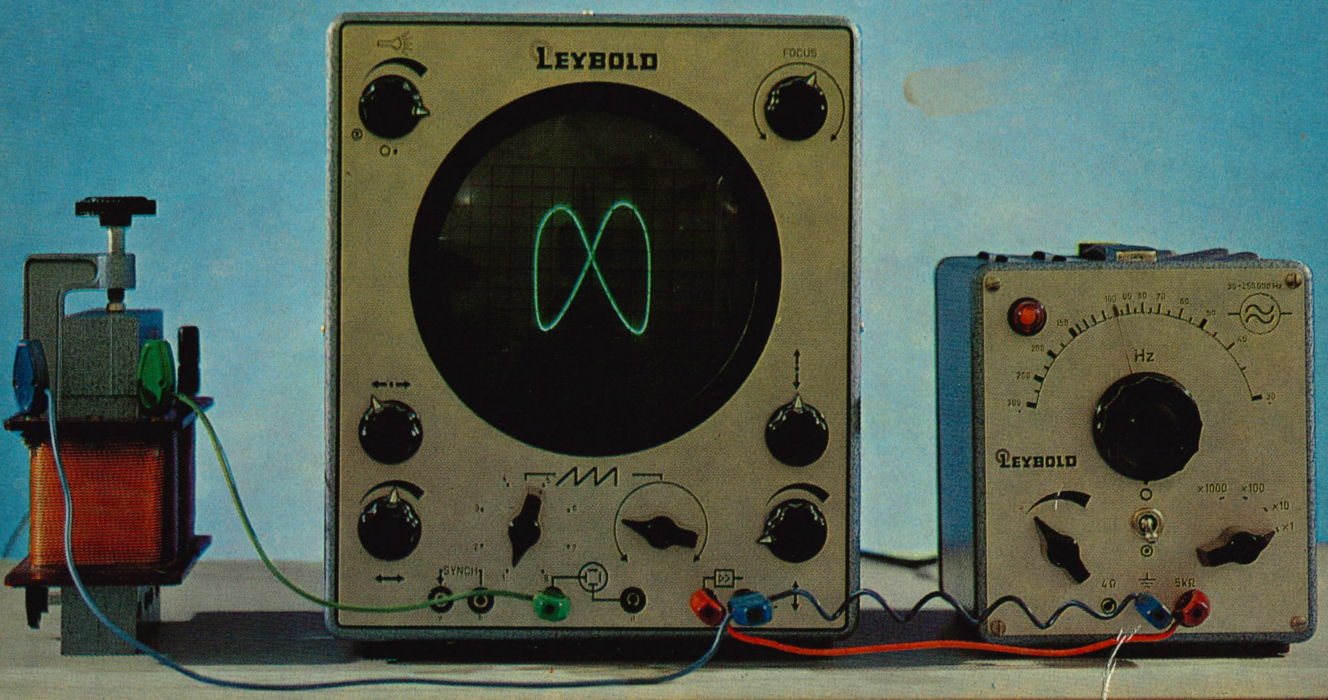
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PHYSICS

APPARATUS FOR TEACHING PURPOSES

LEYBOLD

E. LEYBOLD'S NACHFOLGER • 5 KÖLN-BAYENTAL • GERMANY

PH 52 E

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PHYSICS

APPARATUS FOR TEACHING PURPOSES

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PH 52 E

FOREWORD

Our Physics Catalogue presents itself in a new attire. But this should not be construed as indicating a change of company policy. Far be it – it still remains our proven principle, welcomed by all friends of the House of Leybold, to limit the range of our scientific teaching appliances to those types we consider as being most expedient. The Catalogue, however, has been enlarged to include the many new appliances introduced since 1959.

Yet the fact that the present Catalogue has a much bigger volume than previous editions is really to be attributed to the detailed explanations given for each illustration. We felt that by fully describing the advantages of our appliances, and especially by pointing out in which respect they differ from other, simpler types, we shall be rendering a service to our customers at home and particularly abroad.

Our earlier catalogues consolidated existing relations between the House of Leybold and old associates of the company, and gained us many new friends. We sincerely hope that the present Catalogue will do the same.

We should like to take this opportunity of especially expressing our gratitude to the many old and new friends of our company for the confidence they have shown in us, and for their helpful advice and suggestions, which, needless to say, we always greatly welcome and appreciate.

Cologne, December 1964

(Dr. Manfred Dunkel)

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It is the aim and policy of our firm to design our units of equipment so that they are in line with the most recent knowledge gained in the field of physics and the latest methods applied in the science of teaching. The adoption of up-to-date methods of production and modifications to accessories may lead to variations in design. For this reason, the data and illustrations contained in this catalogue are not binding in all details for the design of the units of equipment supplied.

GENERAL

The bracketed catalogue numbers given in the text, after the name of the respective apparatus, are included so that it will be easier to find the descriptions of these units in the catalogue.

A complete list of catalogue numbers, arranged in numerical order, will be found from page 215 onwards; it gives the page number of each apparatus so that it can be looked up quickly.

The index arranged alphabetically (cf. page 225) includes all units of equipment and accessories listed in the catalogue, together with their relevant catalogue numbers and the pages on which they are to be found.

Symbols and Units. Just as in our other literature, we aim at conforming to the recommendations of the competent committees with respect to symbols and units of physical quantities. In previous editions, we used the unit of force $1\ \mathrm{N} = \frac{\mathrm{kg\ m}}{\mathrm{s}^2}$ (cf. page 18) which belongs to the international system of units.

In this catalogue, we have used for the first time the symbol μm (micrometre) instead of $\mu = 10^{-6}$ m, and the symbol nm (nanometre) in place of m$\mu = 10^{-9}$ m.

In future, we shall follow largely the recommendations of the SUN Commission of the International Union of Pure and Applied Physics [Document U.I.P. 9 (S.U.N. 61—44) 1961].

Accordingly, the symbols of physical quantities, for example, are given in *italics* and the units in upright letters.

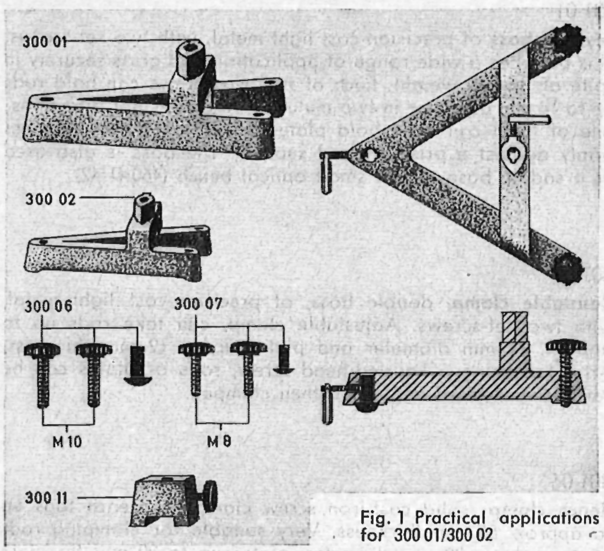
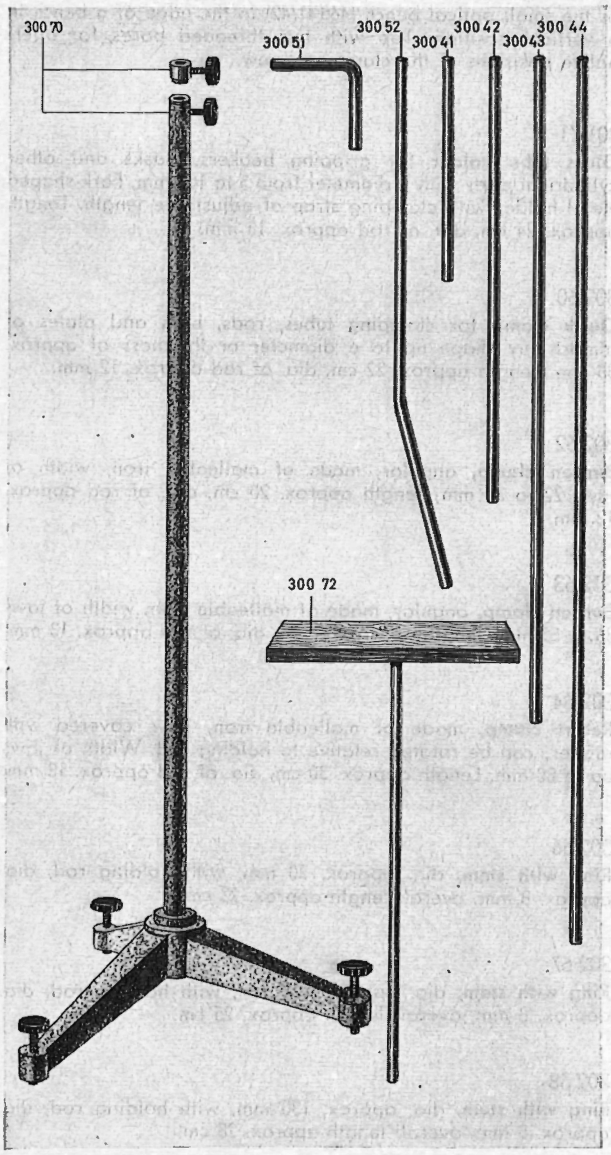


Fig. 1 Practical applications for 300 01/300 02



300 01
Stand base, A-shaped, length of sides: 28 cm, weight: approx. 4 kg.
Sturdy, solid base, not likely to topple even with extremely one-sided loads. The T-bores in the cross bar and the apex can take stand rods up to approx. 14 mm diameter. These can be held firmly between the edges of a longitudinal groove and a set-screw opposite to it (cf. Fig. 1). Threads or cones on the stand rods have thereby been rendered superfluous. Two set-screws are supplied with the base. Both arms are provided with threaded bores for levelling screws (300 06).

300 02
Stand base, A-shaped, length of sides: 20 cm, weight: approx. 1.3 kg.
Both arms are provided with threaded bores to take levelling screws (300 07). Otherwise, as with stand base 300 01.

300 06
Pair of levelling screws (M 10×55), for accurate levelling of stand base 300 01. These levelling screws, and a rivet-shaped insertion supplied with them as a third point of support, make for convenient adjustment of any assembly, even on uneven surfaces.

300 07
Pair of levelling screws (M 10×55), for accurate levelling of and use as for levelling screws 300 06.

300 11
Saddle base (Lens base), metal base with lateral clamping screw, area of base approx. 60×50 mm², height approx. 55 mm, weight approx. 0.9 kg; can take rods of up to 14 mm diameter. Makes for stable arrangement in spite of small area of base. For optical experiments these bases can be placed over a metal scale (311 02/03) and moved along it.

300 41 – 300 44

Stand rods, dia. 12 mm, nickel-plated; 0.25 m long . .	300 41
0.50 m long . .	300 42
0.75 m long . .	300 43
1.00 m long . .	300 44

300 51
Stand rod, dia. 12 mm, bent at right angles, nickel-plated; length of each arm approx. 10 cm. Required, in particular, to mount mercury vapour lamp (451 15) on the small optical bench (460 41/42).

300 52
Stand rod, dia. 12 mm, with one-third inclined at 15°, 60 cm long, nickel-plated. Required for mounting the illuminating lamp for mirror-and-scale reading with the gravitation torsion balance (332 10) or the school mirror galvanometer (532 10).

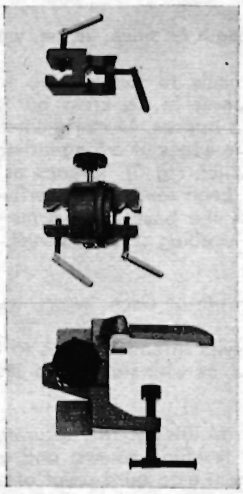
300 70
Demonstration stand, height approx. 110 cm, on stable tripod base (length of legs approx. 30 cm), with 3 levelling screws; can take rods of up to 12 mm diameter. A setting ring, by which the inserted rods are held at the desired height while being freely rotatable, is supplied with the stand. The stand is particularly suitable for holding the small optical bench (460 41/42) or the apparatus table (300 72).

300 72
Apparatus table, wood, surface area 38×25 cm², 18 mm thick; with stand rod (dia. 12 mm, length 50 cm) which screws into the threaded bore at the centre of the plate.
The apparatus table is very useful for setting up measuring or demonstration apparatus which is to stand out from the general assembly in a clearly visible manner.

We recommend mounting the table on one of the following supports:

Demonstration stand	300 70
or	
Bench clamp	301 06
or	
Stand base	300 01

300 75
Laboratory stand
For description and illustration, please see appendix, p. 206.



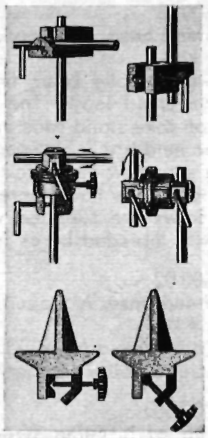
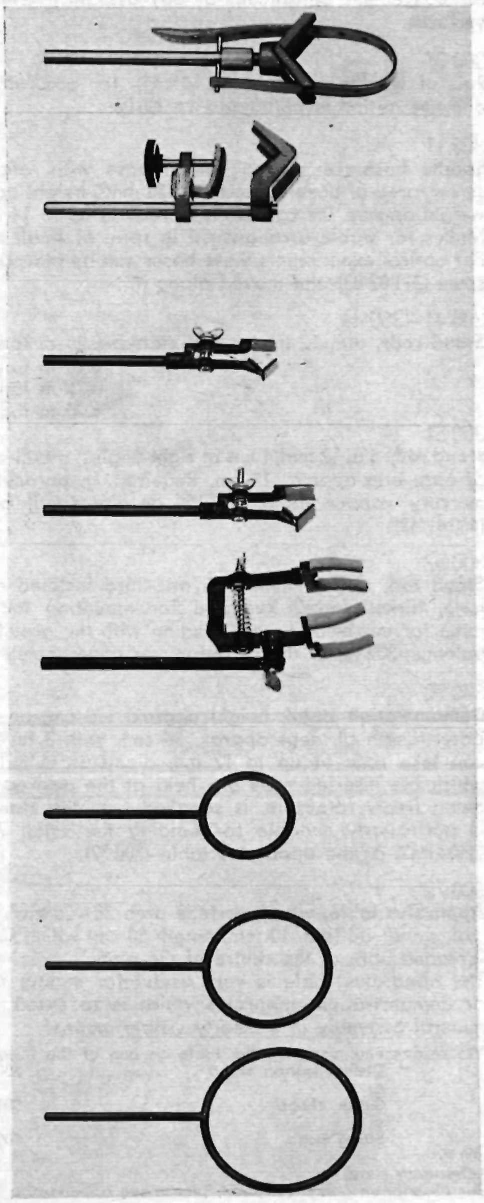


Fig. 2 Practical applications for 301 01, 301 03 and 301 06



301 01

Leybold boss of precision-cast light metal, with two set-screws. This boss has a wide range of application and grips securely in spite of its low weight. Each of the two screws can hold rods up to 14 mm diameter in two mutually perpendicular directions; one of them can even hold plates of up to 12 mm thickness firmly against a prism-shaped support. The boss is also used as a saddle base on the small optical bench (460 41/42).

301 03

Rotatable clamp, double boss, of precision-cast light metal, with two set-screws. Adjustable clamp, can take rods up to approx. 14 mm diameter and plates up to 12 mm thickness. After loosening a knurled-head screw, rods or plates can be set to any desired angle and then clamped.

301 06

Bench clamp; solid cast-iron screw clamp for bench tops up to approx. 55 mm thickness. Very suitable for clamping rods up to approx. 30 mm diameter, plates up to 20 mm thickness or the small optical bench (460 41/42) to the edge of a bench in a vertical position. Top with two threaded bores for alternative positions of the clamping screw.

301 71

Glass tube holder for gripping beakers, flasks and other cylindrical parts with a diameter from 5 to 100 mm. Fork-shaped metal holder with clamping strap of adjustable length. Length approx. 24 cm, dia. of rod approx. 13 mm.

302 60

Quick clamp for clamping tubes, rods, bars and plates of almost any shape up to a diameter or thickness of approx. 80 mm. Length approx. 22 cm, dia. of rod approx. 12 mm.

302 62

Bunsen clamp, angular, made of malleable iron, width of jaws 22 to 37 mm; length approx. 20 cm, dia. of rod approx. 13 mm.

302 63

Bunsen clamp, angular, made of malleable iron, width of jaws 36 to 55 mm; length approx. 24 cm, dia. of rod approx. 13 mm.

302 64

Retort clamp, made of malleable iron, jaws covered with rubber; can be rotated relative to holding rod. Width of jaws up to 80 mm. Length approx. 30 cm, dia. of rod approx. 13 mm.

302 66

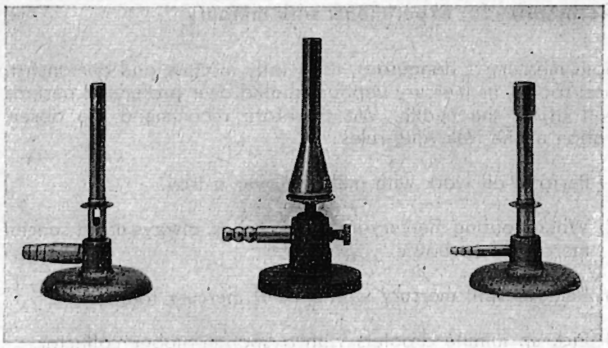
Ring with stem, dia. approx. 70 mm, with holding rod, dia. approx. 8 mm, overall length approx. 23 cm.

302 67

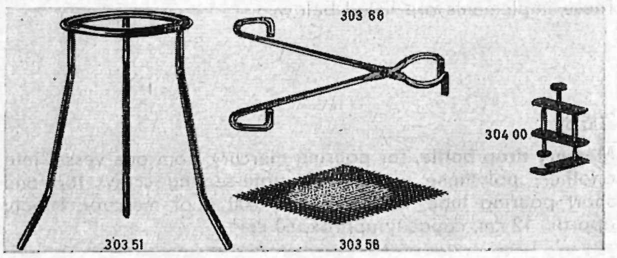
Ring with stem, dia. approx. 100 mm, with holding rod, dia. approx. 8 mm, overall length approx. 25 cm.

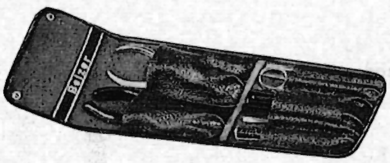
302 68

Ring with stem, dia. approx. 130 mm, with holding rod, dia. approx. 8 mm, overall length approx. 28 cm.



303 03 303 07 303 10





310 02

598 15

303 03
Bunsen burner for coal gas, with sleeve for regulating air supply; brass burner tube, dia. 11 mm; for connection to gas tubing (int. dia. 8 mm, 307 66); height approx. 14 cm.

303 07
Teclu burner for coal gas, with screws for regulating gas and air supply; nickel-plated burner tube, dia. 13 mm; for connection to gas tubing (int. dia. 8 mm, 307 66); height approx. 17 cm.

303 10
Bunsen burner for propane gas, with sleeve for regulating air supply, burner tube, dia. 11 mm and hose nipple, dia. 6 mm; height approx. 14 cm.

303 11
Bunsen burner for butane gas

303 12
Set of 3 gas cartridges
For descriptions and illustrations, please see appendix, p. 206.

303 51
Tripod, wrought-iron, height approx. 18 cm, dia. of ring approx. 100 mm.

303 52
Tripod, wrought-iron, height approx. 21 cm, dia. of ring approx. 120 mm.

303 58
Asbestos-coated wire gauze, size approx. 16×16 cm².

303 68
Crucible tongs, of stainless, acid-resistant steel, double curved; length approx. 20 cm.

304 00
Tube clamp, designed by Hofmann, nickel-plated, one strap can be turned aside; for closing gas and water carrying rubber tubes up to approx. 20 mm diameter; size approx. 30×30 mm².

309 49
Fishing line, 20 m, made of finest raw silk, twisted; max. load 4 kg, dia. approx. 0.5 mm.

305 00
GREEN's lens tissue, especially soft material made of long plant fibres, chemically inactive; for cleaning of lenses and other optical parts and of high-grade insulators; folder holding 50 sheets, size 20×30 cm².

309 78
Quik-stick, spray-on adhesive, please see appendix, p. 209

309 79
Red sealing wax, bar, approx. 100 g.

309 80
Filter paper, 5 sheets; size 58×58 cm²; grained, medium fast.

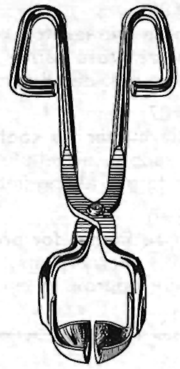
310 02
Tool bag "Recklinghausen", made of coloured plastic material, with two press studs; contains the following chromium-plated tools made of VANADIUM-Extra steel:

1 Side-cutting pliers, 145 mm long, non-insulated
1 Combination chain-nose pliers, 160 mm long, insulated
1 Universal scissors with round tips, 110 mm long
1 Voltage detector, made as a screwdriver with 2.8 mm wide edge and insulated handle
1 each of loose screw driver blades of 3.5 and 4.5 mm width and 1 piercer, to be inserted in a plastic handle also contained in the bag.

598 15
Movable stand "Recklinghausen", wooden stand on wheels, approx. 1.15 m high; with three trays, one slotted board for connecting leads and holders for cables.

Practical piece of furniture for storing and transporting frequently used implements and tools which can be arranged tidily and always accessible, also saves time in assembling demonstration arrangements.

306 80



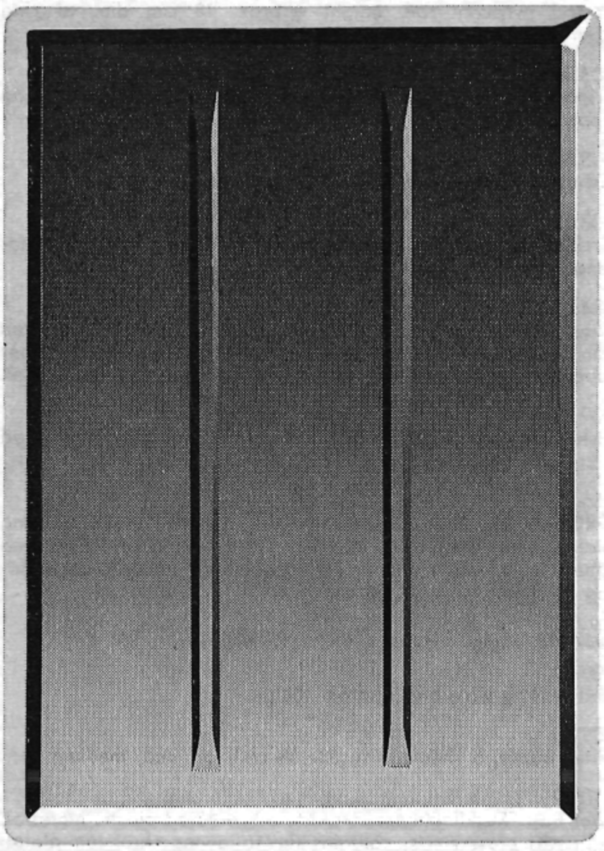
303 75

Accessories for experiments with mercury

Spilt mercury is dangerous, especially in class and demonstration rooms, as mercury vapour inhaled over prolonged periods will affect the health. We therefore recommend the observation of the following rules:

1. Perform all work with mercury over a tray.
2. When pouring mercury into glass tubes, always use a special mercury drop bottle.
3. Remove spilt mercury with special mercury tongs.
4. Pick up minute droplets with a sponge-rubber collector.

These implements are listed below:



309 63

306 80

Mercury drop bottle, for pouring mercury from one vessel into another; polythene vessel with tight-sealing screw top and short pouring tube, holds approx. 800 g of mercury. Height approx. 12 cm, capacity approx. 60 cm³.

303 75

Mercury tongs, made of stainless, acid-resistant steel, with sharp edges for picking up mercury drops.

309 63

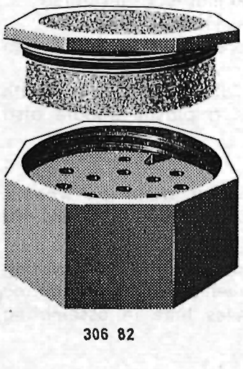
Mercury tray, made of polystyrene, coloured, with spouts. Recommended for all kinds of work with mercury. Size approx. 62×44 cm², 7 cm high.

306 82

Mercury collector, for picking up minute mercury droplets. These are taken up by the pores of a latex sponge inserted into the lid of a plastic container (dia. approx. 85 mm). Complete with 1 spare sponge.

306 87

Spare sponges, of latex foam, for mercury collector (306 82). Set of four in a bag.



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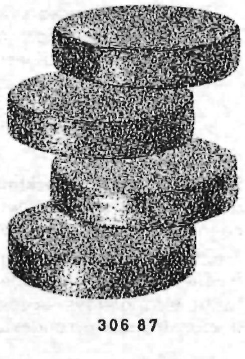


306 87

177 21

Mercury, chemically pure, for measuring instruments 1 kg

177 23

Mercury, chemically pure, for measuring instruments 150 g

177 24

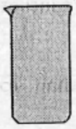
Mercury, chemically pure, for measuring instruments 50 g

Mercury, 99.99 B.P., 50 g in drop bottle (in Great Britain only)

304 19–304 23

Beakers, made of Jena glass, tall shape, with lips

Cat. No.	304 19	304 20	304 21	304 22	304 23
Capacity cm³	50	100	250	400	600
Height mm	65	80	115	130	145
Dia. mm	38	45	60	70	78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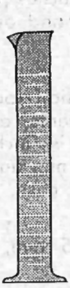
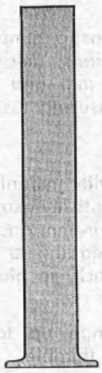

307 30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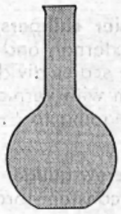
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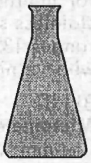
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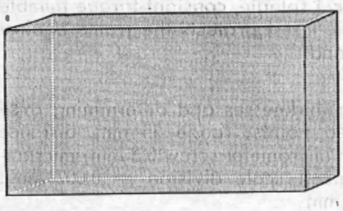
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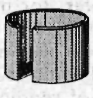
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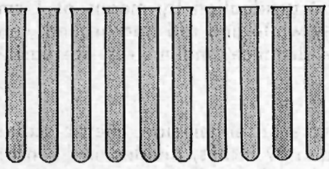
307 01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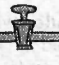
309 03


307 16

307 64–307 67

Rubber tubing, laboratory grade, red; 1 m long.

Cat. No.	307 64	307 65	307 66 *)	307 67
Int. dia. mm	6	7	8	10
Wall thickness mm	1.5	2	2	2

*) Gas tubing; for vacuum and pressure tubing see section "Vacuum".

307 30–307 33

Measuring cylinders, made of glass, tall shape, with graduation marks, lips and bases.

Cat. No.	307 30	307 31	307 33
Capacity cm³	100	250	1,000
Graduation cm³	1	2	10

316 56

Glass cylinder with base, for hydrometer experiments; approx. 36 cm high, int. dia. approx. 50 mm, wall thickness 2 mm, with polished rim.

304 33

Flat-bottomed flask, long neck (boiling flask), made of Jena glass, with beaded rim;
Height 20 cm, Capacity 500 cm³
Neck: dia. 35 mm, Bulb: dia. 105 mm.

304 37

Conical flask, narrow neck, made of Jena glass;
Height 15 cm, Capacity 300 cm³,
Neck: dia. 31 mm; greatest dia. 87 mm.

304 60

Set of 3 watch glasses, for projection experiments; dia. 40, 60 and 90 mm, respectively; approx. 1.5 mm thick; curved, rim finely ground.

306 92

Pneumatic trough, made of glass, rectangular; size 30×16×16 cm³.

306 97

Insert for pneumatic trough, made of aluminium, dia. 84 mm, height 5.5 cm, with slot for introducing glass tube.

307 01

Glass tubes, assorted; dia. 5–13 mm, length approx. 50 cm; approx. 1 kg.

307 02

Set of glass tubes, dia. 6 mm; approx. 250 g.

307 14

Set of 10 test tubes, of Jena glass; approx. 16 cm high, dia. 16 mm.

307 16

Glass connecting tap, 2 mm bore.

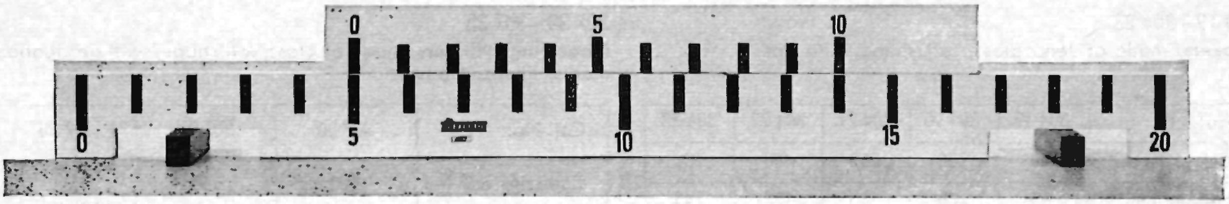
309 03

Porcelain evaporating basin, dia. approx. 85 mm, height approx. 3.5 cm; semi-deep shape with spout, glazed.

307 94–99

Rubber stoppers, grey

Cat. No.		Upper dia. mm	Lower dia. mm	Length mm
307 94	Without holes	31	25	30
307 95	With 1 hole			
307 96	With 2 holes			
307 97	Without holes	38	31	35
307 98	With 1 hole			
307 99	With 2 holes			



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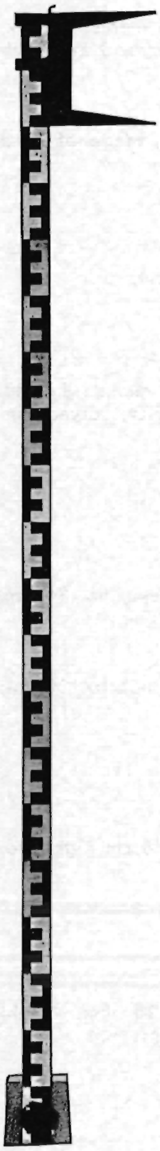
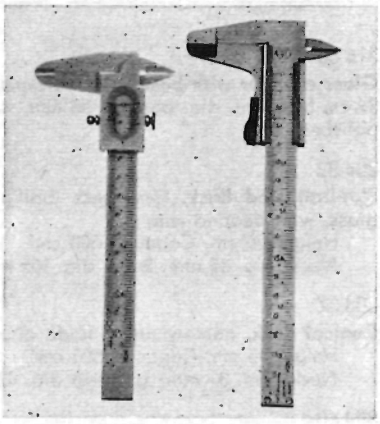
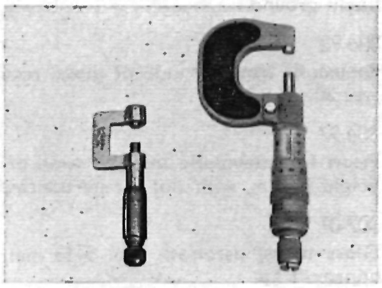


311 22



311 52 311 54



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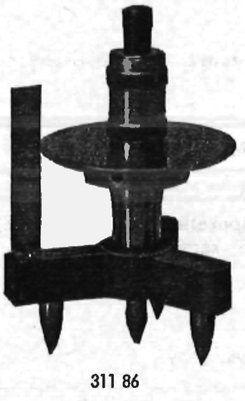


311 86

313 21

311 77

311 02

311 03

311 27
Model of vernier, made of wood, approx. 1 m long, graduated in 5 cm, with slider. On one side of slider divisions are $^{9}/_{10}$ of those of main scale, on the other $^{11}/_{10}$; either can be used at will.

311 52
Vernier callipers, made of plastic, simple design; scales with millimetre and $^{1}/_{16}$ inch divisions, measuring ranges 120 mm with vernier reading to $^{1}/_{10}$ mm and 5 inches with vernier reading to $^{1}/_{128}$ inch; for measuring inside and outside diameters and depths.

311 54
Precision vernier callipers, with instant-action locking device for internal, external, and depth measurements; all hardened, stainless steel; scales divided in mm and in $^{1}/_{16}$ inch, measuring ranges 135 mm with vernier reading to $^{1}/_{10}$ mm and $5^{3}/_{8}$ inches with vernier reading to $^{1}/_{128}$ inch; in plastic case.

311 81
Micrometer screw-gauge, range up to 15 mm, reading to $^{1}/_{100}$ mm, with constant-torque thimble.

311 83
Precision micrometer screw-gauge, range up to 25 mm, reading to $^{1}/_{100}$ mm; with stainless steel spindle, constant-torque thimble and locking device. A plastic insert protects the frame against heat transferred from the hand.

311 86
Spherometer, for measuring thicknesses and determining radii of curvature; with hardened points; range 25 mm, distance between feet 50 mm; pitch of micrometer screw 0.5 mm; micrometer head with 250 divisions (1 scale division = 0.002 mm). Accuracy of reading: 0.001 mm.

313 21
Revolution counter, in case, $100 \times 40 \times 35$ mm^3; registers up to 10,000 revolutions, can be used for rates up to 6,000 r.p.m.; with one spindle for both directions of revolution, knurled knob for zero setting and slip-on sleeve with rubber cone.

311 02
Metal scale, 1 metre long, cm graduation by means of 1 cm wide black bars on alternately white and red background, can be read from a considerable distance; millimetres are easily estimated.

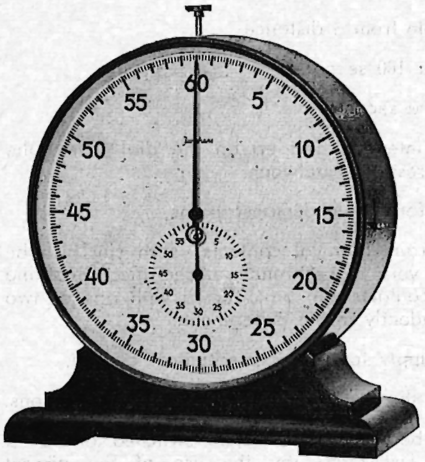
311 03
Wooden rule, with double scale on either side; metric scale: 1 m, divided in mm; inch scale: 39 inches, divided in $^{1}/_{8}$ inch; with brass ends; approx. 25 mm wide.

311 22
Vertical scale, for use in experiments on elastic deformation, with capillary filter tubes (exponential decay), Torricelli tubes and other vertical length measurements. Consists of a scale (311 02) mounted in a stable base, and a cursor with two pointers that automatically locks on the scale. The two pointers of the cursor are spaced 100 mm apart; the upper one cuts the graduations on the scale.

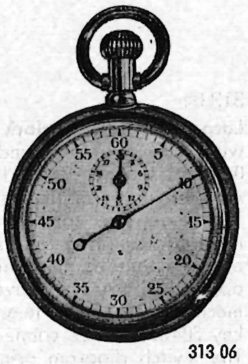
311 77
Steel tape measure with automatic rewind and centimetre and inch scales; capsule coated with coloured varnish, dia. 50 mm. Range: 2 m divided in mm, and 78 inches subdivided in $^{1}/_{16}$ inches, etched on curved steel tape.

Measurement of time in class

When measuring time in class we attach great value to suiting the measuring device to the problem in hand. If these matters are examined more closely it will be found that there are four different time-measuring ranges within which certain definite accuracies are desirable. In order to take account of this, time-measuring instruments of different degrees of accuracy are required, with suitable, matching accessories to start the process that is to be measured.



313 05



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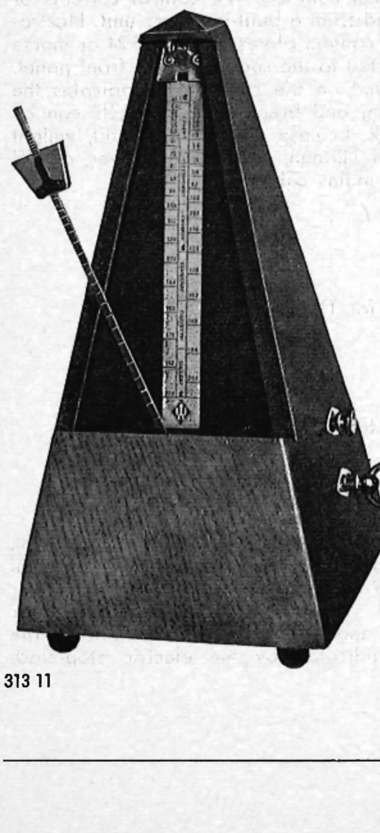


313 11

(a) For time measurements of the order of magnitude of hours to minutes, with an accuracy of a few tenths of a second, we use hand-operated stop-clocks (313 05 or 313 06) with mechanical clockwork. The time standard is the natural frequency of the balance-wheel and hair-spring of the clock.

(b) For time measurements of the order of magnitude of 100 seconds to a few tenths of a second, with an accuracy of $^1/_{100}$ second, we use the electric stop-clock, which is operated by electro-mechanical contacts. The time standard is the frequency, 50 or 60 c/s, of the supply mains. In the $^1/_{100}$ second range, especially, there are a number of important, basic measurements.

(c) For time measurements of the order of magnitude of a few seconds to a few milliseconds with an accuracy of $^1/_{10,000}$ second, we use an electronic scaler that is started and stopped by light barriers or electric impulses. In this case the time standard is a quartz-controlled electronic frequency generator (for details see the section "Electronics").

(d) One example of a measurement of even shorter time intervals of the order of magnitude of 10^{-7} seconds is the measurement of the velocity of light. In this case, the measurement of time is reduced to the measurement of the frequency of rotation of a light beam, and the deflection of this beam.

313 05

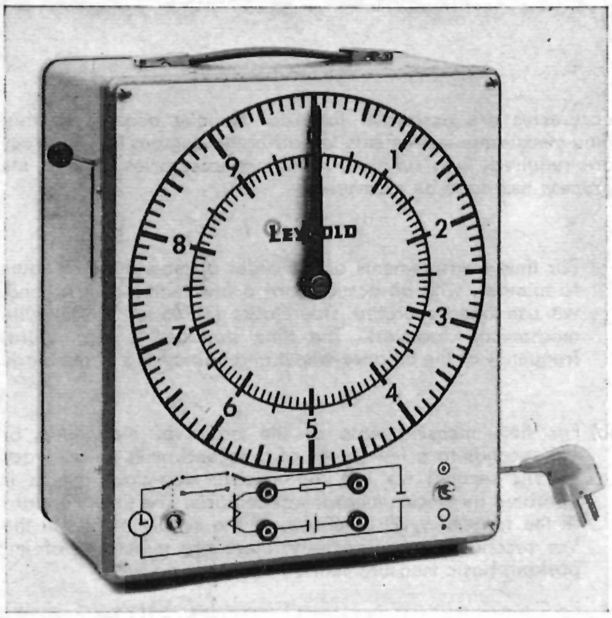
Stop-clock, with clockwork, start-, addition- and stop-lever, and set-zero key; in metal case on base; dia. approx. 210 mm, height approx. 27 cm. Large dial: 0–60 seconds, seconds divided into fifths; small dial: 0–60 minutes.

313 06

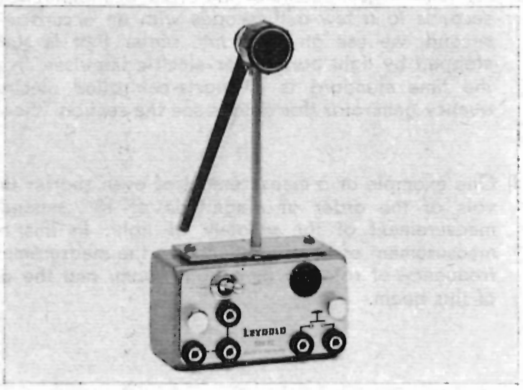
Stop-watch, precision watch with dials for 60 seconds and 30 minutes, seconds divided into fifths; Swiss precision clockwork with unbreakable spring; antimagnetic, chromium-plated case with double lid; dia. approx. 50 mm.

313 11

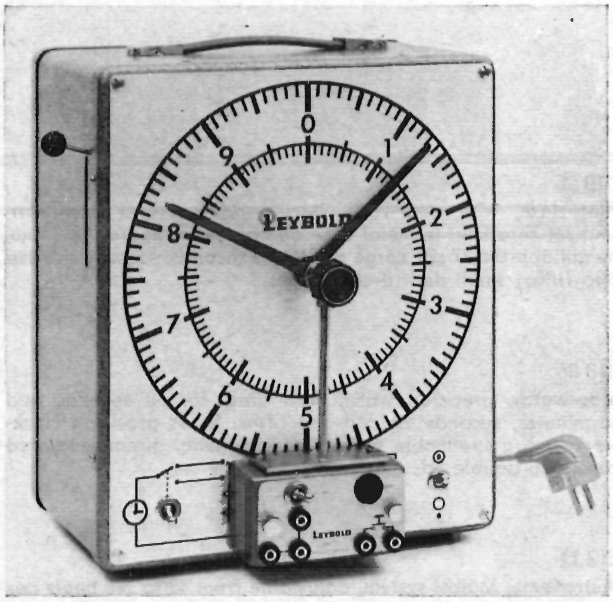
Metronome, Mälzel system, adjustable from 40 to 208 beats per minute, with clockwork, hard wood case, brown matt finish; area of base approx. 11×12 cm^2, height approx. 23 cm.



313 04



559 72



PH 2001

Fig. 3 Large electric stop-clock with pre-set time-switch in position

Large electric stop-clock

The large electric stop-clock has been designed to cover the range from 100 to 0.1 seconds with an accuracy of 0.01 seconds and meets all the demands that can be made upon a teaching aid. As is explained in the experimental examples in the next few pages, this clock is particularly suitable for performing time measurements on the basic laws of mechanics.

The most outstanding features are:

- Dial clearly visible from a distance.
- Seconds scale for 100 seconds.
- Reads down to $^1/_{100}$ second.
- Successive time intervals add up on the dial unless the set-zero key is pressed in between.
- Hand operation for simple demonstrations.
- Control by electro-mechanical contacts which can also be operated by the very process under observation. Breaking and making of contacts can be effected with one or two switches, independently of the experimenter.
- Built-in power supply for electro-mechanical control.
- The diagram on the front panel explains the connections.
- The process to be measured can be switched on for a pre-set time interval (by the use of the pre-set time-switch 559 72).

313 04

Large electric stop-clock for 220 V (or 150 V, or 125 V), 50 c/s, with scale 0 to 1 second divided into $^1/_{100}$ seconds and scale 0 to 100 seconds divided into seconds; to be connected to the A.C. mains; operated by a self-starting synchronous motor. The gears are connected to the motor through an electromagnetic coupling with a relay that can be controlled by hand or by means of mechanical contacts. The control currents of approx. 50 mA are derived from a built-in power unit. Electro-mechanical contacts (e.g. contact plates 336 23, 336 24 or morse key 504 52) can be connected to the sockets on the front panel. The switch diagram printed on the front panel indicates the ways in which the making and breaking of contacts can be used to actuate the clock. In case ($31 \times 26.5 \times 16$ cm^3), weight approx. 5 kg, dia. of dial 240 mm, with set-zero lever, cut-off switch, carrier strap and mains cable.

313 02

Large electric stop-clock for 110 V, 50 c/s.

313 08

Large electric stop-clock for 115 V, 60 c/s.

559 72

Pre-set time-switch for the large electric stop-clock (313 02/04/08), for continuous pre-setting of time-intervals when working with demonstration scaler (559 62) and school mirror galvanometer (532 10). Two ranges: $\leqq 1$ s and > 1 s are available, e.g. for frequency measurements and radioactive determinations. The observation period is indicated by the electric stop-clock (cf. Fig. 3).

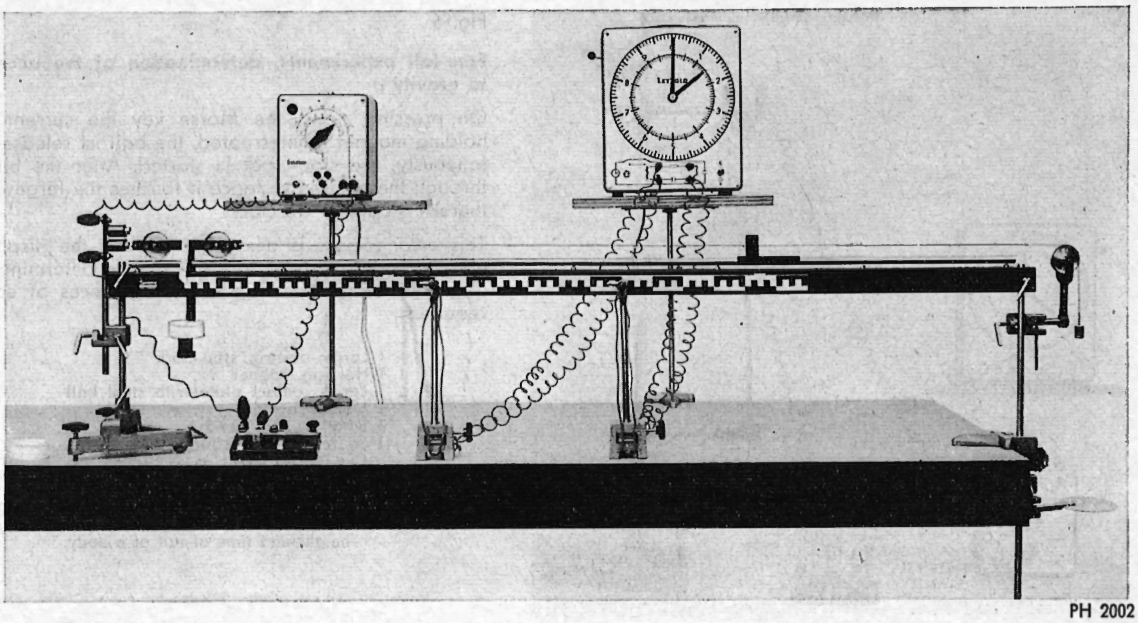


Fig. 4

PH 2002

Displacement-time measurements with Fletcher's trolley and flying start

Essential pieces of equipment:

		Cat. No.
1	Large electric stop-clock	313 02/04/08
1	Fletcher's trolley with accessories	337 30
1	Holding magnet	336 20
2	Small contact plates	336 24
1	Morse key	504 52
1	Source of D.C. yielding approx. 10 V; 1 A	
	Connecting leads as required	
	Stands	

On pressing down the Morse key the current through the holding magnet is interrupted and the trolley is released. The stop-clock is only started when the tongue attached to the trolley has opened the first contact plate when passing it, and stopped as soon as the trolley has reached the second contact plate and actuated it.

This arrangement is used in the following experiments, described in LEYBOLD Physics Leaflets:

DC 531.112.1; b	Velocity with uniform and non-uniform rectilinear motion.
DC 531.612; a	Impulse and momentum.
DC 531.62; a	Potential energy, kinetic energy and friction work demonstrated with Fletcher's trolley.
DC 531.62; b	The work in acceleration, kinetic energy and friction work demonstrated with Fletcher's trolley.

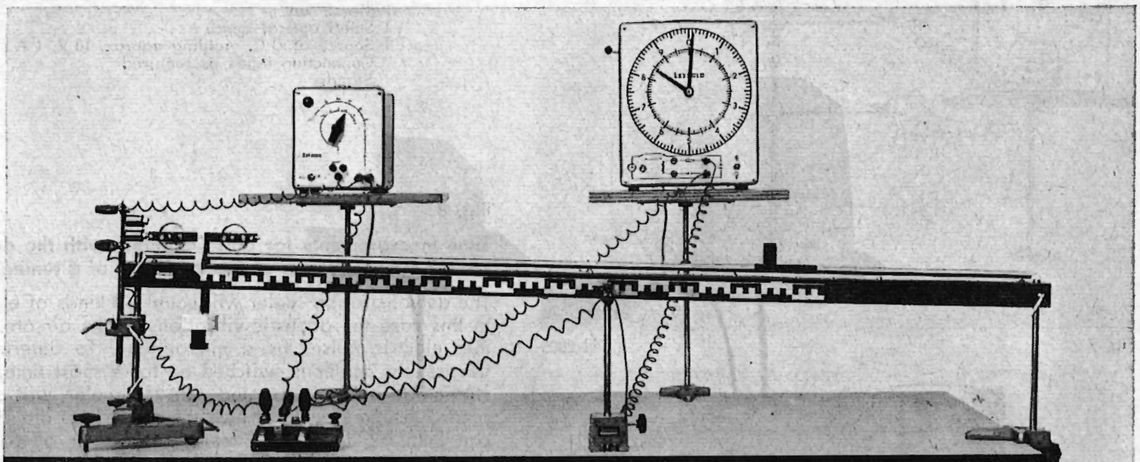


Fig. 5

PH 2003

Displacement-time measurements with Fletcher's trolley, clock started at the beginning of the motion

Essential pieces of equipment:

		Cat. No.
1	Large electric stop-clock	313 02/04/08
1	Fletcher's trolley with accessories	337 30
1	Holding magnet	336 20
1	Small contact plate	336 24
1	Morse key	504 52
1	Source of D.C. yielding approx. 10 V, 1 A	
	Connecting leads as required	
	Stands	

On pressing down the Morse key the current through the holding magnet is interrupted and the trolley is released. Simultaneously the stop-clock is started. After passing through the test distance a tongue attached to the trolley opens the small contact plate and stops the clock.

This arrangement is used in the following experiments, described in LEYBOLD Physics Leaflets:

DC 531.113.1; a	Uniformly accelerated, rectilinear motion.
DC 531.211; b	Mass as a measure of the inertia of bodies.
DC 531.311; c	Fletcher's trolley as an inclined plane, or the Galilean groove.
DC 531.37.03; a	Newton's law of inertia (first law of motion).

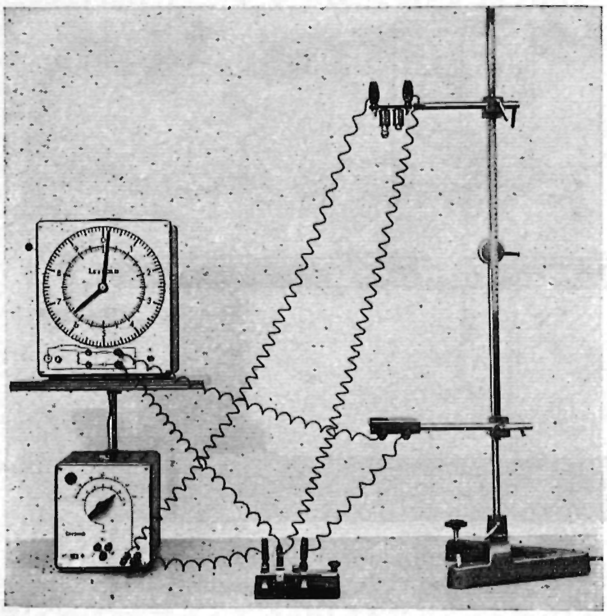


Fig. 6 PH 2004

Fig. 6

Free-fall experiments, determination of the acceleration due to gravity *g*

On pressing down the Morse key the current through the holding magnet is interrupted, the ball ist released and, simultaneously, the stop-clock is started. After the ball has fallen through the desired distance it touches the large contact plate, thereby stopping the clock.

This arrangement is designed to study the displacement-time relation in the case of free fall and to determine the acceleration due to gravity. The following pieces of equipment are required:

	Cat. No.
1 Large electric stop-clock	313 02/04/08
1 Holding magnet	336 20
1 Large contact plate with steel ball	336 23
1 Morse key	504 52
1 Small optical bench	460 42
1 Source of D.C. approx. 10 V, 1 A	
Connecting leads as required	
Stands	

This arrangement is described in "LEYBOLD Physics Leaflets", DC 531.113; a Measurement of the gravitational acceleration from the height and time of fall of a body.

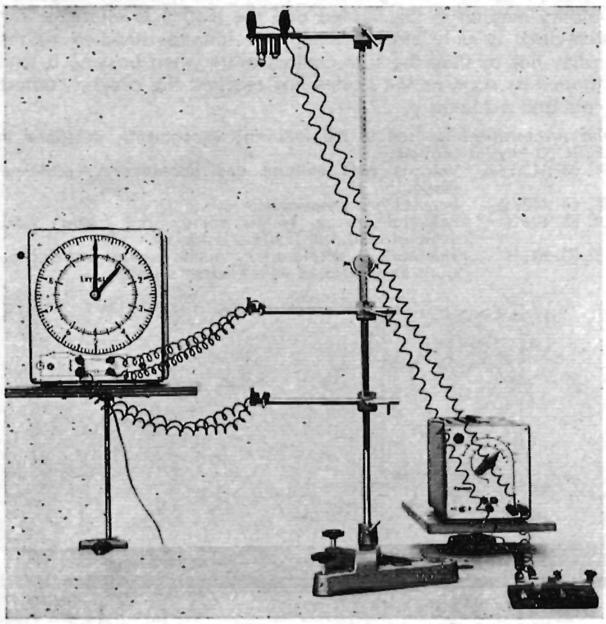


Fig. 7 PH 2005

Fig. 7

Measurement of free-fall velocity

The ball is released when the Morse key is pressed down to interrupt the current through the holding magnet; but the clock is only started when the ball passes the first contact plate and stopped when it actuates the second at the end of the distance chosen for measurement. This arrangement can be used for determining free-fall velocities.

Essential pieces of equipment:

	Cat. No.
1 Large electric stop-clock	313 02/04/08
1 Holding magnet	336 20
2 Small contact plates	336 24
1 Morse key	504 52
1 Small optical bench	460 42
1 Source of D.C. yielding approx. 10 V, 1 A	
Connecting leads as required	
Stands	

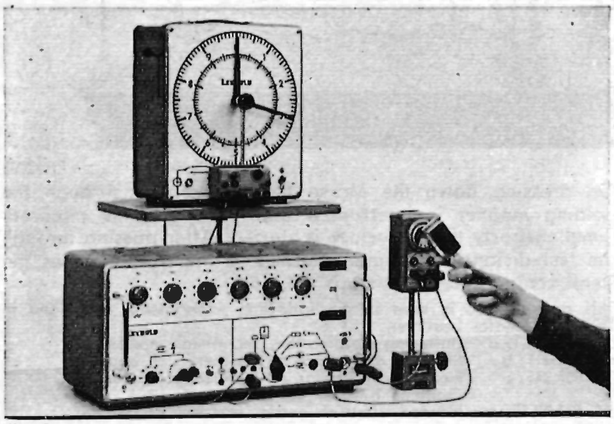


Fig. 8 PH 2006

Fig. 8

Time measurements for pulse counting with the demonstration scaler: Determination of the frequency of a tuning fork

The demonstration scaler will count all kinds of electric pulses. In this case the acoustic vibrations of the air are transformed into electric pulses by a microphone. To determine the frequency, the scaler is switched on for a short time. The electric stop-clock, which is coupled with the scaler, will automatically record the time during which the scaler was on. The frequency can then be determined from the number of pulses counted during this time. Alternatively, the pre-set time-switch enables the time during which the scaler is on to be pre-set; this will render the calculation easier.

The following pieces of equipment are required for these experiments:

	Cat. No.
1 Large electric stop-clock	313 02/04/08
1 Demonstration scaler	559 62
1 Carbon microphone	586 27
1 Tuning fork, 1,700 c/s	411 81
Connecting leads as required	
Stands	
Additionally recommended:	
1 Pre-set time-switch for 313 02/04/08	559 72

We recommend reading our booklet "Descriptions of Experiments with the Demonstration Scaler".

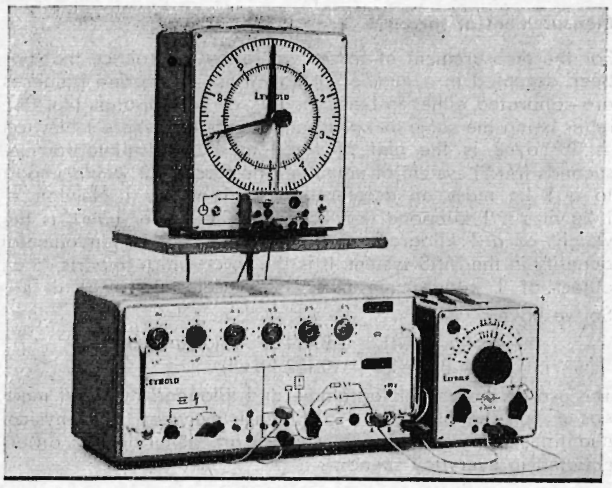


Fig. 9 PH 2007

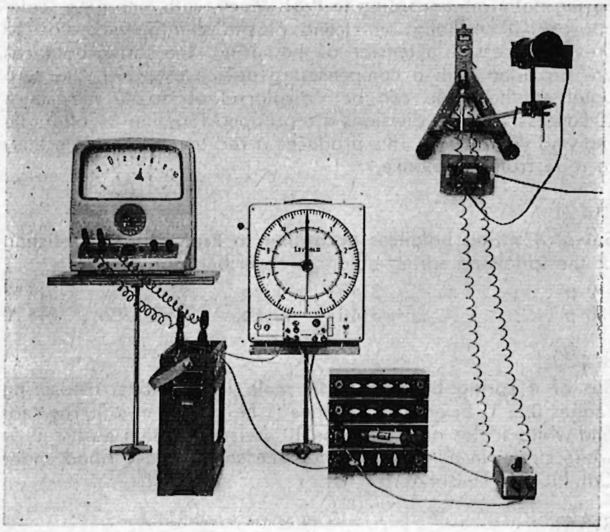


Fig. 10 PH 2008

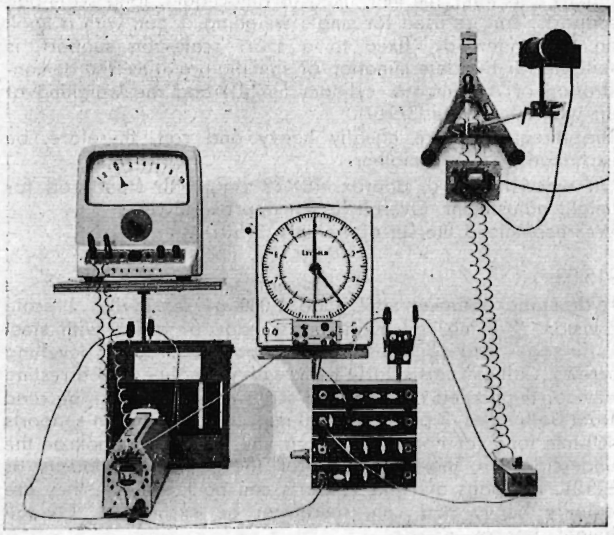


Fig. 11 PH 2009

Fig. 9

Determination of frequencies by counting pulses

The sinusoidal pulses of the RC-oscillator (or of a tuning fork) can be counted with the demonstration scaler. They are fed into the input sockets. The pre-set time-switch plugged into the electric stop-clock and connected to the demonstration scaler permits pre-setting the time during which the scaler is operating.

Apparatus required:

1 Demonstration scaler	559 62
1 Large electric stop-clock	313 02/04/08
1 Pre-set time-switch for 313 02/04/08	559 72
1 RC-oscillator	587 00

We recommend reading our booklet "Descriptions of Experiments with the Demonstration Scaler".

Fig. 10

Calibration of the ballistic mirror galvanometer in ampere-seconds *)

The mirror galvanometer is connected to a source of voltage through a high resistance. As long as the pre-set time-switch keeps the circuit closed, a small current will flow. Therefore, the arrangement is suitable for the production of square current impulses, the duration of which can be pre-set with the stop-clock and pre-set time-switch. These will cause the mirror galvanometer to perform ballistic deflections whose magnitudes are proportional to the product: current × time. After taking some readings with different values, a graph of the mirror galvanometer sensitivity can be plotted. Instead of the pre-set time-switch, a Morse key can be used. In this case the time is not pre-set, but measured.

For this experiment the following pieces of equipment are needed:

1 Large electric stop-clock	313 02/04/08
1 School mirror galvanometer	532 10
1 Sensitivity control for same	532 11
1 Pre-set time-switch for 313 04	559 72
or	
1 Morse key	504 52
1 Demonstration multirange meter	531 86
1 Resistance box for precision measurements, 0.1 to 1111 Ω, ±2%	536 77
1 Resistance coil, 10 kΩ	536 19
Connecting leads as required	
Illuminating device for mirror galvanometer	
Stands and source of voltage	

*) See "LEYBOLD Physics Leaflets" DC 537.741.5; c.

Fig. 11

Calibration of the ballistic mirror galvanometer in volt-seconds *)

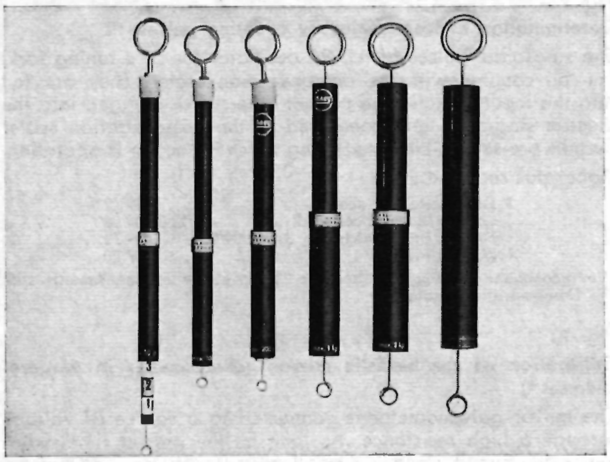
The mirror galvanometer is supplied with a low voltage derived from a low-resistance potential divider circuit as long as the contact of the pre-set time-switch is closed. At the moment of closing this contact, the stop-clock is started. By this arrangement square voltage impulses can be produced, the duration of which can be pre-selected with the pre-set time-switch.

These cause the mirror galvanometer to make ballistic deflections, the magnitudes of which are proportional to the product: voltage × time. After some measurements with different values the mirror galvanometer can be calibrated. Instead of the pre-set time-switch (559 72), a morse key (504 52) may be used. In that case the time is indicated on the stop-clock.

For this experiment, the following pieces of apparatus are needed:

1 Large electric stop-clock	313 02/04/08
1 School mirror galvanometer	532 10
1 Sensitivity control for same	532 11
1 Pre-set time-switch for 313 04	559 72
or	
1 Morse key	504 52
1 Demonstration multirange meter	531 86
1 Resistance box for precision measurements, 0.1 to 1111 Ω, ±0.2%	536 77
1 Rheostat, 110 Ω	537 24
1 Wattmeter coil	516 30
Connecting leads as required	
Illuminating device for the mirror galvanometer	
Stands and source of voltage	

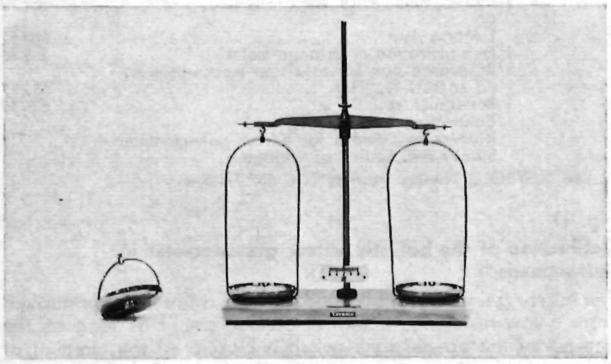
*) See "LEYBOLD Physics Leaflets" DC 537.741.5; d



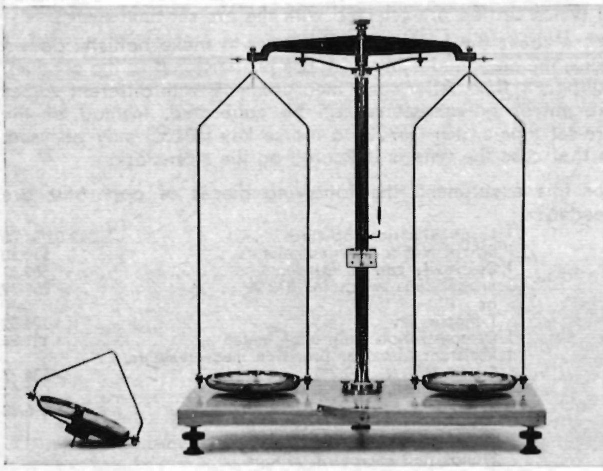
314 11–314 20

Cat. No.	Max. load	Divisions	Total length cm
314 11	10 p	1/10 p	19
314 14	100 p	1 p	19
314 15	200 p	2 p	20
314 16	500 p	5 p	21
314 17	1 kp	10 p	21
314 18	2 kp	20 p	22
314 20 *	10 kp	100 p	23

(* **without** zero setting)



315 01



315 03

Measurement of forces

For the measurement of forces we follow a practice that has been accepted in a number of countries: our spring balances are calibrated either in Newtons (N), or in kiloponds (kp) (the latter being the same as kg wt) and ponds (p), where 1 Newton = 10^5 dyne is the unit of force in the metre-kilogramme-seconds (MKS) system of units, i.e. the force that would impart to a 1 kg mass an acceleration of 1 m s^{-2}. 1 Newton = 1 kg m s^{-2}. 1 kilopond (kg, kg wt), on the other hand, is the weight of a 1 kilogramme mass, and is not a fundamental quantity in the MKS system. It is the force which imparts to an object of 1 kilogramme mass the acceleration 9.81 m s^{-2}. So we have:

1 kp (= kg wt) = 9.81 N (= 981,000 dyne)
1 N = 0.102 kp (= 0.102 kg wt)

The use of the units kilogramme and kilopond makes it much easier for the student to distinguish between the physical quantities of mass and weight which are generally not differentiated in everyday speech.

314 11 – 314 20

Spring balances according to Prof. Maey, with emerging scale, approx. 10 cm long; in strong plastic sheath, with stop to prevent excessive extension of the spring. The spring balances are provided with a compensating device by which the zero point of the scale can be displaced up to 40 mm. Each 10 successive scale divisions are grouped together by alternate red and white rings. This produces a red and white scale easy to read from a distance.

314 21

Set of 4 spring balances according to Prof. Maey, consisting of the following spring balances described above:

10 p	314 11	1 kp	314 17
100 p	314 14	10 kp	314 20

314 30

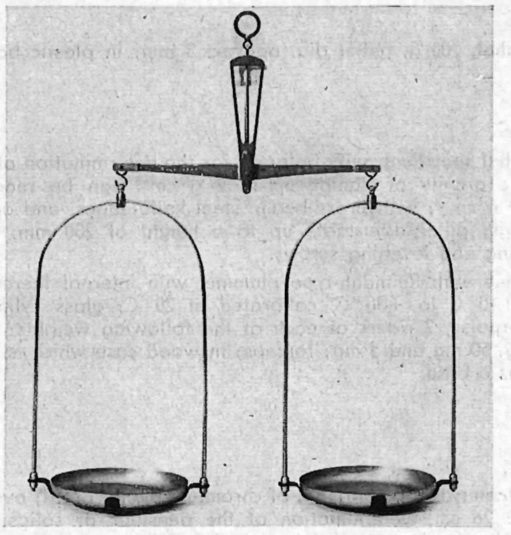
Set of 4 spring balances with scale in Newtons, measuring ranges 0.1; 1; 5; and 10 Newtons (1 N = 1 kg m s^{-2}). The red-and-white scales accommodate 10 divisions within each red or white circle. In all other respects the same as described under Cat. No. 314 11–314 20.

315 01

Hydrostatic balance, max. load: 200 g. Sensitivity: 1 scale division ≙ 20 mg; with steel knife-edges in agate bearings; 2 pans, diameter 100 mm, fixed to detachable, long scale-pan supports, can be used for single weighing. 1 pan with a hook on the under-side, fixed to a short scale-pan support, is suitable for the determination of specific gravities, the demonstration of Archimedes' cylinder (362 01) and the weighing of air with the sphere (379 07).
The three pans are equally heavy and can, therefore, be exchanged one for another.
On wooden board, approx. 18×35 cm^2, with stand rod for height adjustment. Overall height approx. 43 cm.
We recommend the set of weights (315 31).

315 03

Hydrostatic balance, max. load 1,000 g; sensitivity: 1 scale division ≙ 8 mg; all metal parts made of brass, with steel knife-edges and agate bearings, on base board with levelling screws. Column particularly high, with plumbline and arresting device; duplicated pointers and scales; can therefore be read from both sides. 3 pans, dia. 140 mm, two of them on supports 460 mm long for normal weighing, the third, with hook on the underside, on short support; for the same experiments as 315 01. The pans and the supports can be taken off; they are equally heavy and can, therefore, be exchanged. Overall height: approx. 63 cm.
For weighing we recommend set of weights (315 32).



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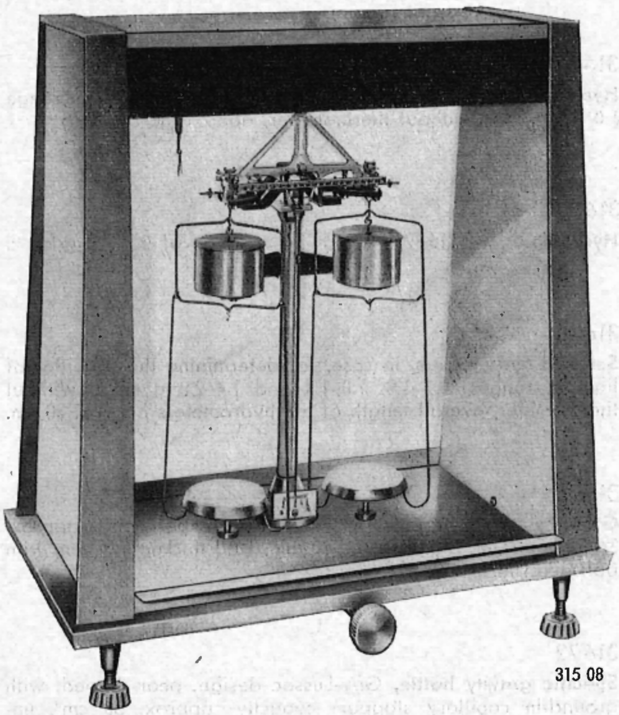
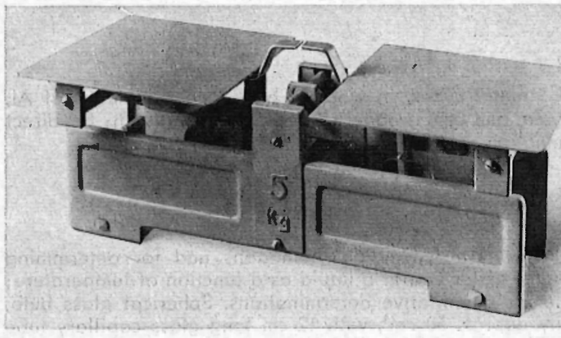


315 08



315 22

315 06

Balance for class work in schools, consisting of one beam with pointer and scale and two pans on equally long pan-supports. The pans are removable, matched and marked, and made of metal. The balance can either be held in the hand or suspended from a stand. Sensitivity: 1 scale division $\triangleq$ 20 mg; max. load: 200 g. Overall height: approx. 36 cm; diameter of scale-pans: 100 mm.

315 08

Analytical balance, max. load 200 g, sensitivity: 1.2 mm/mg, can be read to $^1/_{10}$ mg; with agate axles and bearings, air-damped, with rider adjustment. Dia. of pans 75 mm.

In modern, corrosion-resistant, plastic case (approx. 51×29×52 cm^3), suitable for the tropics; with glass front and rear wall. The front wall is balanced by a counterweight and can, therefore, be raised without effort. The rear wall is detachable. The instrument is provided with levelling screws and a level gauge for horizontal adjustment.

We recommend set of weights 315 30.

315 22

Laboratory scales, max. load 5 kg, sensitivity: 1 g; with 2 square steel plates of approx. 18 cm edge length, with steel plate understructure, knives and bearings of hardened special steel; bearings protected against disengagement and displacement. The balance is officially calibrated.

We recommend sets of weights 315 34 and 315 36.

315 30

Set of weights, 1 mg to 200 g, with rhodium-plated weights, 200 g to 1 g made of brass, 500 mg to 10 mg of pure nickel, 5 mg to 1 mg of aluminium. Rider weights: 2 aluminium 10 mg riders. With brush to remove dust and forceps with ivory tips. In mahogany case with removable plastic insert for the fractional gramme weights, with velvet-covered lid.

315 31

Set of weights, 10 mg to 200 g; the 200 g to 1 g weights made of brass, the 500 mg to 50 mg of German silver and the 20 mg to 10 mg of aluminium; with forceps, in hardwood box with lid.

315 32

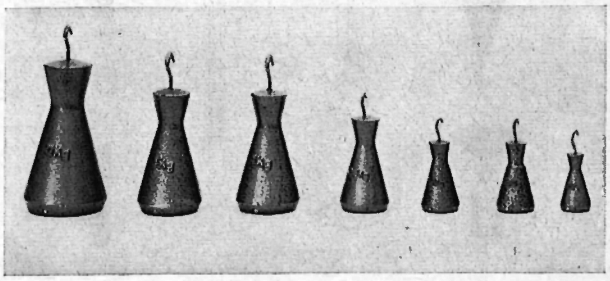
Set of weights, 10 mg to 1,000 g; the 1,000 g to 1 g weights made of brass, the 500 mg to 50 mg of German silver and the 20 mg to 10 mg of aluminium; with forceps, in hardwood box with lid.

315 34

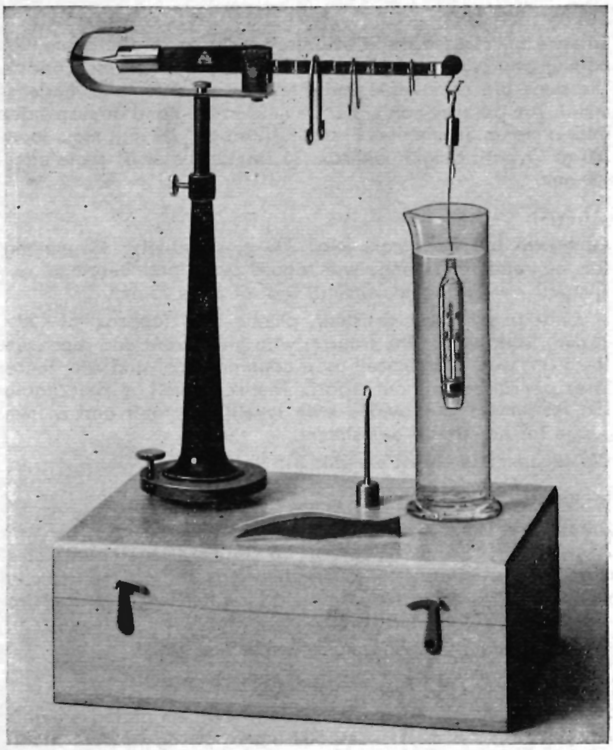
Set of weights, 1 g to 1,000 g; the 1 to 50 g weights made of brass, the larger ones of black varnished cast iron, in wooden block without lid.

315 36

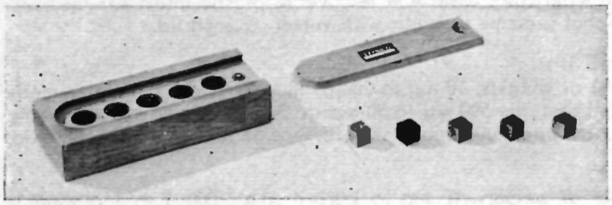
Set of 7 weights, of pleasing, practical shape, cast-iron; each weight provided with a suspension hook and a transverse bar at the bottom for attaching further weights. The set is particularly convenient to handle in a great many experiments and comprises the following weights: 2 kg, 2×1 kg, 500 g, 2×200 g, 100 g.



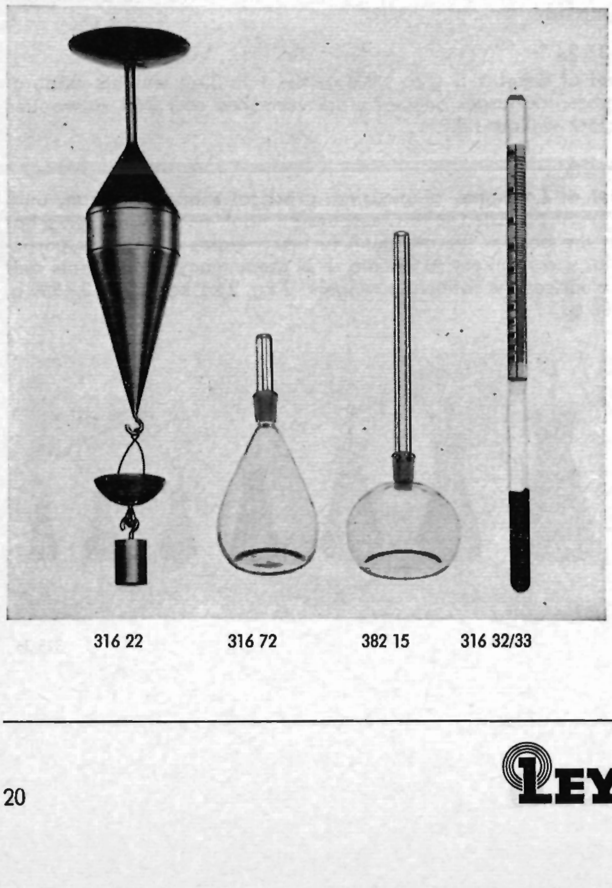
315 36



316 06



362 23



316 22 316 72 382 15 316 32/33

315 76
Lead shot, 200 g, pellet dia. approx. 3 mm; in plastic bottle.

316 06
Westphal specific gravity balance, for the determination of the specific gravity of liquids up to 2 g cm^{-3} can be read to 1×10^{-4} g cm^{-3}; with brass beam, steel knife-edges, and agate bearings; pillar adjustable up to a height of 280 mm, with clamping and levelling screws.

Complete with Reimann-type plummet with internal thermometer, +10° C to +30° C, calibrated at 20° C; glass cylinder, counterpoise, 2 riders of each of the following weights: 5 g, 500 mg, 50 mg and 5 mg; forceps; in wood case which is also used as a base.

316 22
Hydrometer, Nicholson type, of chromium-plated brass; overall height: 26 cm. Determination of the densities of solids and liquids by application of the principles of buoyancy. Complete with bucket and pan.
A set of weights is additionally required (e.g. 315 31).

316 32
Hydrometer, for determining the densities of liquids; range 1.0–2.0 g cm^{-3}, without thermometer, approx. 30 cm long.

316 33
Hydrometer, as 316 32, but having a range of 0.7–1.0 g cm^{-3}.

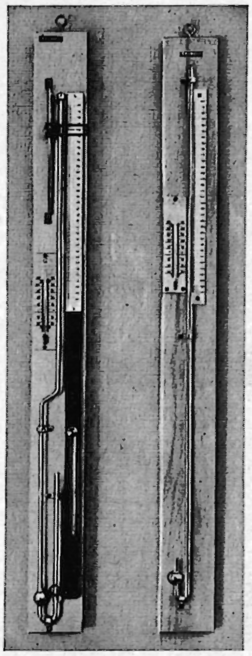
316 46
Set of 3 hydrometers, in case, for determining the densities of liquids; ranges: 0.7–1.0, 1.0–1.4 and 1.4–2.0 g cm^{-3}; without thermometer, overall length of the hydrometers approx. 30 cm.

316 56
Glass cylinder with base, for hydrometer experiments; approx. 36 cm high, int. dia. approx. 50 mm, wall thickness 2 mm, with polished rim.

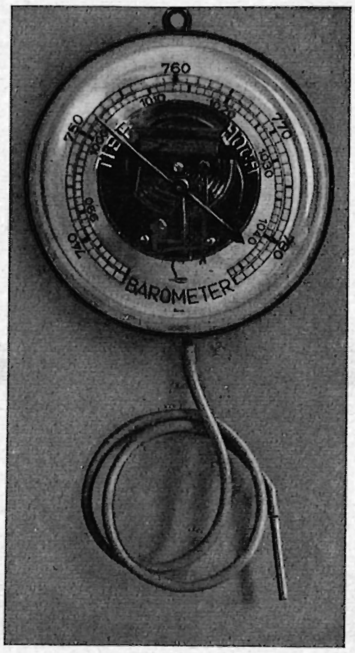
316 72
Specific gravity bottle, Gay-Lussac design, pear-shaped, with ground-in capillary stopper; capacity: approx. 50 cm^3, uncalibrated.

362 23
Set of 5 metal cubes, in wooden box. One cube each of Al, Pb, Fe, Zn, and brass; edge length: precisely 10 mm; for direct determination of the densities of these substances.

382 15
Dilatometer, for density determinations and for determining the volume expansion of a liquid as a function of temperature; suitable for quantitative determinations. Spherical glass bulb, capacity approx. 50 cm^3, with 12 cm long glass capillary tube with millimetre graduation and ground-glass joint.



317 14 317 13



317 19

Measurement of atmospheric pressure

317 13

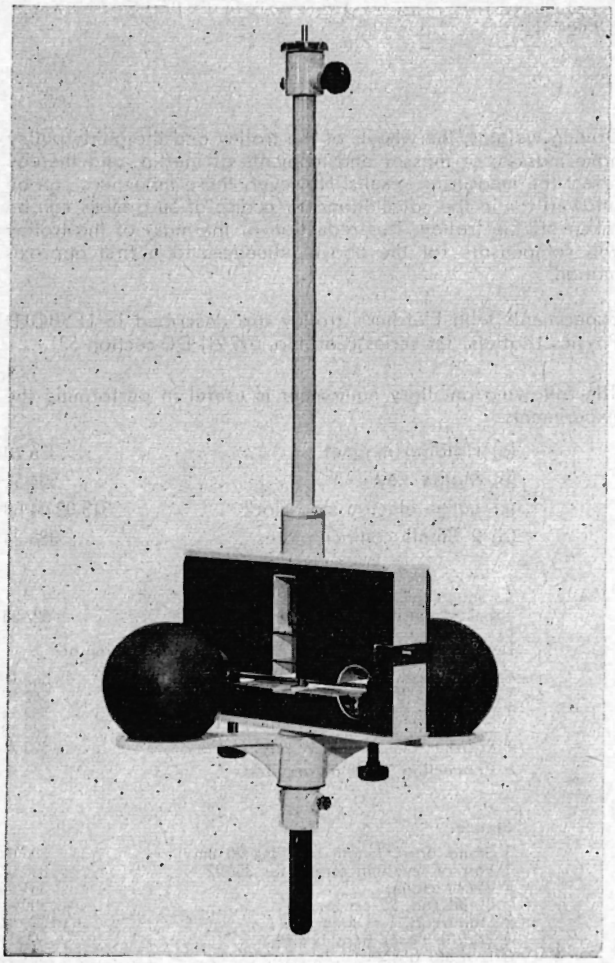
Mercury barometer, easy-to-read, measuring range 480–800 mm Hg (Torr); on rigid, 1 m long base board. The short limb of the glass tube flares out into a spherical bulb, so that changes of atmospheric pressure do not noticeably affect the lower mercury level. Hence, reading the upper mercury level suffices. With suspension fitting, thermometer and mercury filling.

317 14

Barometer, syphon type; mercury barometer for precise readings, range 480–800 mm Hg (Torr); on 1 m long base board. The rise and fall of the mercury level in the short limb of the glass tube can be compensated for by adjusting the zero mark on the displaceable scale support. With suspension fitting, thermometer and mercury filling.

317 19

Demonstration aneroid barometer; aneroid barometer with two scales, ranges: 735–785 mm Hg (Torr) and 980–1,045 mb; scale diameter: 90 mm, diameter of casing: 130 mm. Mechanism under glass cover clearly visible; for continuous observation of the normal atmospheric pressure. For demonstration purposes the pressure can be changed arbitrarily by blowing air into the rubber tube connected to the casing.



332 10

Gravitation

332 10

Gravitation torsion balance, designed by *Schürholz*.
Experiments demonstrating the mutual attraction, due to gravitation, of two objects, and the quantitative determination of the gravitation constant*) are among the fundamental experiments in physics. They necessitate measuring extremely small forces, of the order of, for example, 10^{-7} in the case of two masses of 20 g and 1.5 kg, respectively, spaced a few centimetres apart.

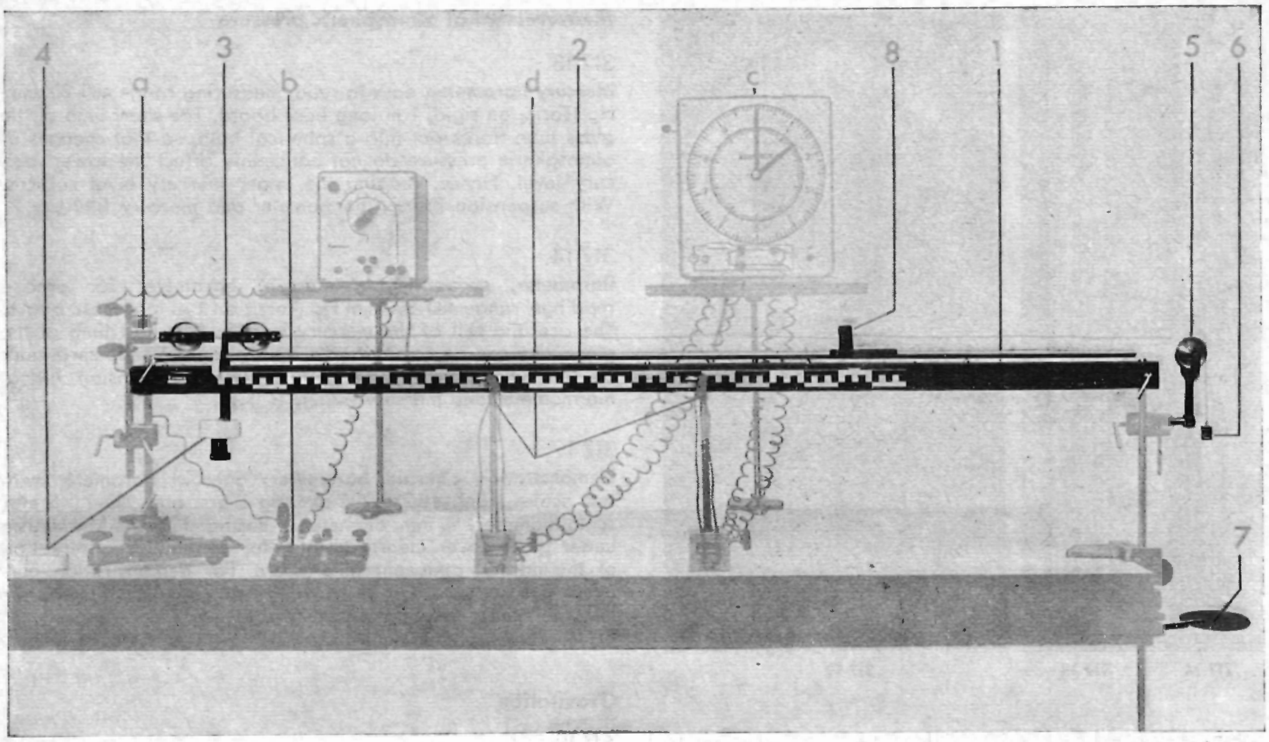
According to *Coulomb* and *Cavendish*, such forces can be measured with a highly sensitive torsion balance having a long period of oscillation and provided with a mirror, lamp and scale. *Schürholz* has devised a handy, compact form of this balance that is practicable for use in schools. With this apparatus the gravitation constant can be determined during a single lesson.

The system of the balance consists of a bronze torsion band and 2 lead balls arranged 5 cm away from the band on a transverse beam. It oscillates with a period of 10 minutes; the oscillations are visible from outside. A concave mirror of approx. 300 mm focal length for lamp-and-scale reading is attached to the system. The apparatus is moreover provided with a swivelling support carrying 2 balls of 1.5 kg mass each. The displacement of the system after changing the position of these latter balls can be read by means of the lamp-and-scale apparatus. By measuring the acceleration of the masses moving towards one another it is possible to obtain, within a few minutes, values for the gravitation constant with an error of less than 10%, and these can be considerably improved by increasing the period of measurement.

The instrument is supplied complete with lead balls, swivelling support and short rod by which it may be secured to a permanent support. Stands and illuminating device are additional. We recommend using the following parts for permanent mounting on a wall, and for illumination:

1	Stand base, 28 cm	300 01
1	Pair of levelling screws for 300 01	300 06
2	Leybold bosses	301 01
1	Stand rod, angular, 60 cm long	300 52
1	Lamp-house	450 60
1	Lamp, 6 V, 30 W	450 51
1	Single-lens condenser with sliding diaphragm	460 17
1	Transformer, 6 V, 30 W	562 76
	Connecting leads as required	

*) cf. "LEYBOLD Physics Leaflets" DC 531.51; a, DC 531.51; b.



337 30 (cf. Fig. 4, page 15)

337 30

Fletcher's trolley, apparatus for introducing the fundamental laws of kinematics and dynamics, for measurements on the horizontal motion of the trolley. By slightly inclining the track, friction can be largely compensated for. The course of uniform and non-uniform motion on the entire length of the track (1.5 m) can be observed and the relations between velocity, acceleration and impulse can be derived therefrom and the basic laws of kinematics and dynamics can be investigated.

In combination with the large electric stop-clock and two small contact plates exact measurements of the motion of the trolley as a function of, for example, the driving force or the mass of the trolley, which can be varied by attaching weights to it, are possible.

The assembly depicted above consists of the following parts:

1. Track, 1.5 m long, made of polished, nickel-plated round steel rod, mounted on a hollow square-sectioned steel support along its entire length, and aligned; at both ends the square support is provided with a 12 mm hole with setscrew for fastening it on stands.
2. Scale, 1 m long, with coloured segments and centimetre graduation, displaceable.
3. Trolley on two wheels with journal bearings and device for holding metal discs to increase the mass of the trolley; mass: 0.5 kg.
4. 2 Metal discs, 0.5 kg each, with central bore; to double or treble the mass of the trolley.
5. Guide pulley for guiding the driving cord.
6. Weights to provide driving forces of 10, 20, 30, and 40 p (g wt).
7. Plate to stop driving weights.
8. Adjustable friction brake.

Driving weights, the wheels of the trolley and the guide pulley have masses, or masses and moments of inertia, and thereby affect the measuring results. However, these influences can be allowed for in the calculations, or a disc of 50 g mass can be taken off the trolley. This reduction of the mass of the trolley will compensate for the above influences to a first approximation.

Experiments with Fletcher's trolley are described in LEYBOLD Physics Leaflets, 1st series (Cat. No. 599 21) DC-section 531.

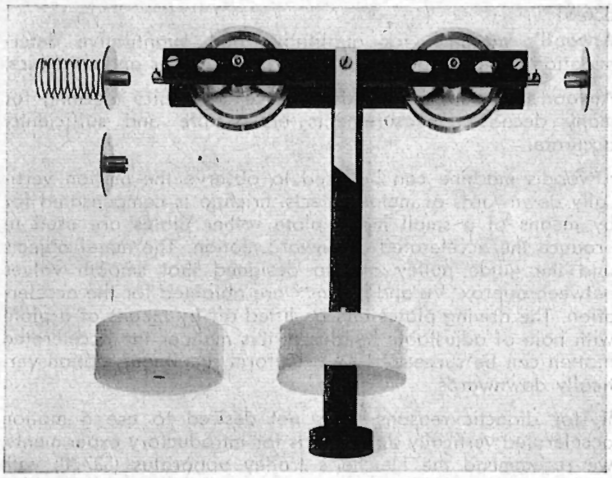
The following ancillary equipment is useful in performing the experiments:

(a) Holding magnet	336 20
(b) Morse key	504 52
(c) Large electric stop-clock	313 02/04/08
(d) 2 Small contact plates	336 24

As source of D.C., approx. 10 V, 1 A, e.g. Low tension power supply	522 38
or Demountable demonstration transformer, consisting of:	
1 U-core with yoke	562 11
1 Clamping device	562 12
1 Coil with 500 turns	562 14
1 Coil with 46 turns	562 18
1 Rectifier element, 20 V, 6 A	523 71
Connecting leads as required	

Stands:

1 Stand base, length of sides 20 cm	300 02
1 Pair of levelling screws for 300 02	300 07
1 Bench clamp	301 06
1 Stand rod, 25 cm long	300 41
1 Stand rod, 1 m long	300 44
2 Saddle bases (lens bases)	300 11
3 Leybold bosses	301 01
1 Spirit level	361 03



337 36

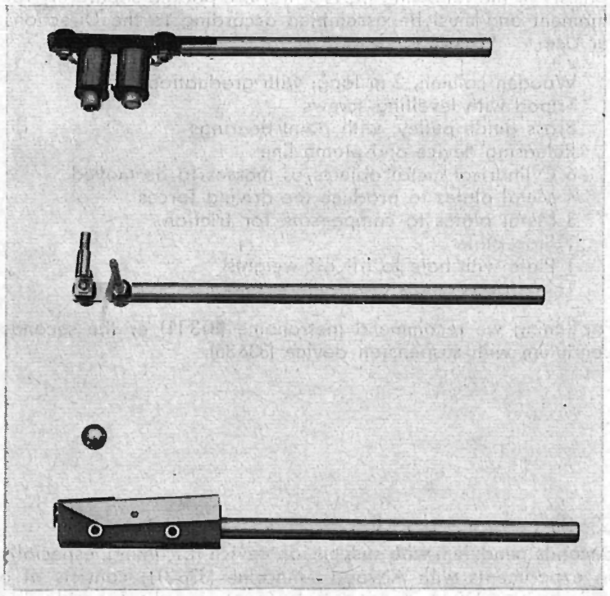
337 36

Second trolley for track, extends range of application of track to experiments on the conservation of momentum, elastic and inelastic collisions and on the potential energy of a stretched spring. Complete with two buffers and a helical spring for collision experiments and two metal discs of 0.5 kg mass each to double and treble the mass of the trolley.

This second trolley is an accessory to the Fletcher's trolley apparatus. Equipment needed for the experiments:

1	Fletcher's trolley apparatus, complete	337 30
1	Stand base, length of sides 20 cm	300 02
1	Pair of levelling screws for 300 02	300 07
1	Bench clamp	301 06
1	Stand rod, 25 cm long	300 41
1	Stand rod, 1 m long	300 44
2	Leybold bosses	301 01
1	Spirit level	361 03
	Soft wax	

cf. "LEYBOLD Physics Leaflets", DC 531.66; a



From top to bottom: 336 20 336 24 336 23

336 20

Holding magnet, for starting kinematic processes by the interruption of an electric circuit, especially for free-fall experiments with steel balls and for experiments with Fletcher's trolley (337 30).

With 4 mm sockets for electrical connections, on stand rod, dia. 12 mm, length approx. 15 cm. Requires approx. 10 V, 1 A D.C.

336 23

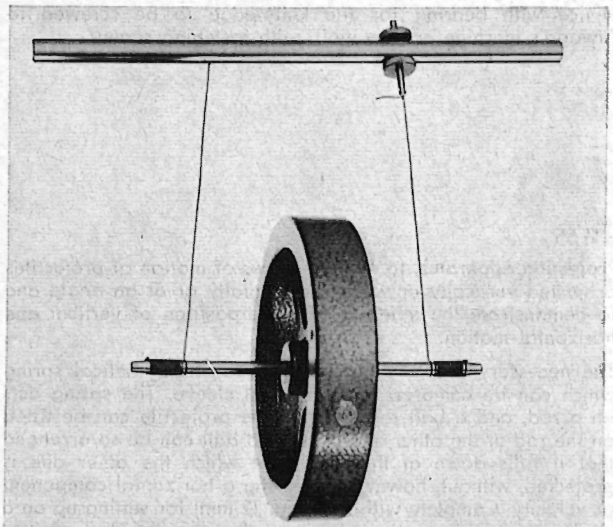
Large contact plate, for electric timing in free-fall experiments with steel balls. The falling ball impinges upon the front part of the contact plate, which is protected by a rubber disc, thereby breaking the circuit to the large electric stop-clock (313 02/04/08). Complete with stand rod, approx. 19 cm long, two 4 mm sockets for making electric connections and one steel ball, dia. 15 mm.

An experimental arrangement is depicted in Fig. 6, p. 16.

336 24

Small contact plate, for electric timing by opening a low-inertia contact, especially for experiments with the large electric stop-clock (313 02/04/08) and Fletcher's trolley (337 30). When closed, the contact plate is held by a small permanent magnet. Complete with stand rod, approx. 23 cm long, with two 4 mm sockets for making electric connections. For many experiments with Fletcher's trolley, two are required.

Preferably set up in saddle base (300 11).

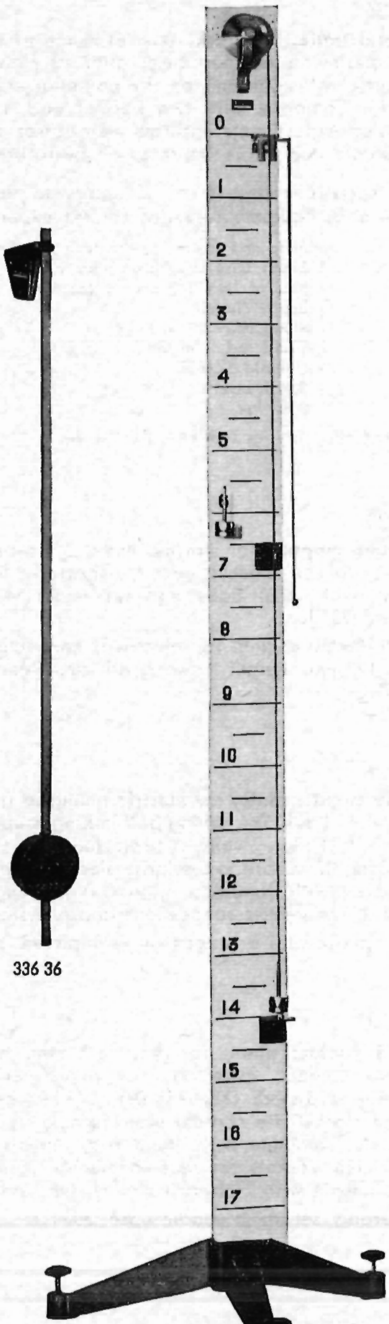


331 22

331 22

Maxwell's wheel. Flywheel, dia. approx. 13 cm; mass approx. 0.7 kg; for demonstrating the transformation of potential into kinetic energy. The wheel can also be mounted on a balance (e.g. 315 22) to measure the inertia force created on acceleration*). Complete with shaft and adjustable suspension, but without stand equipment.

*) This experiment is described in "LEYBOLD Physics Leaflets", DC 531.312.1; a



336 36

336 31

336 31

Atwood's machine, for qualitative and quantitative determination of the fundamental laws of kinematics and dynamics.

Atwood's machine has held its place in physics teaching for many decades; measurements are simple and sufficiently accurate.

Atwood's machine can be used to observe the motion vertically downwards of metal objects. Friction is compensated for by means of a small metal plate; other plates are used to produce the accelerated downward motion. The metal objects and the guide pulley are so designed that smooth values between approx. $^{1}/_{30}$ and $^{3}/_{10}$ ms^{-2} are obtained for the acceleration. The driving plates can be lifted off by means of a plate with hole of adjustable height; in this manner the accelerated motion can be succeeded by a uniform rectilinear motion vertically downwards.

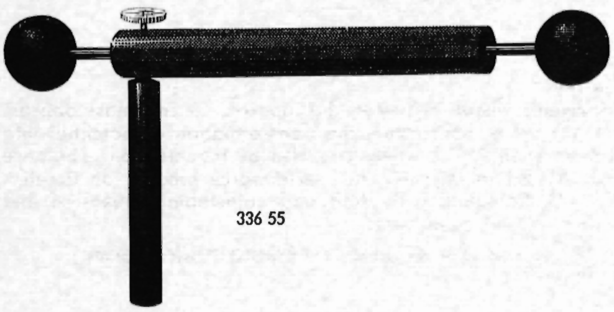
If, for didactic reasons, it is not desired to use a motion accelerated vertically downwards for introductory experiments, we recommend the Fletcher's trolley apparatus (337 30) with trolley running horizontally on the rail. Atwood's machine consists of the following parts which are packed separately for shipment and must be assembled according to the Directions for Use:

Wooden column, 2 m long, with graduation
Tripod with levelling screws
Brass guide pulley, with point bearings
Releasing device and plumb line
6 Cylindrical metal objects as masses to be moved
4 Metal plates to produce the driving forces
3 Metal plates to compensate for friction
1 Stop plate
1 Plate with hole to lift off weights
Thin string

For timing we recommend metronome (313 11) or the seconds pendulum with suspension device (336 36).

336 36

Seconds pendulum with suspension device for timing, especially in experiments with Atwood's machine (336 31); consists of a rail, approx. 110 cm long, with knife-edge, a displaceable disc (bob) to adjust the period of oscillation and a suspension device with bearing for the knife-edge to be screwed to Atwood's machine or to a wall; with fastening screws.

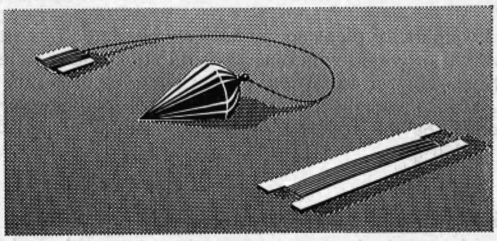


336 55

336 55

Projection apparatus, to study the laws of motion of projectiles projected vertically upwards, horizontally or at an angle and to demonstrate the independent superposition of vertical and horizontal motion.

The necessary energy is supplied by a strong helical spring which can be compressed in a metal sleeve. The spring acts on a rod, and a ball representing the projectile can be fitted on the rod at the other end. A second ball can be so arranged that it falls down at the instant at which the other one is projected, without, however, receiving a horizontal component of velocity. Complete with rod (dia. 12 mm) for setting up on a stand at various angles, with two plastic balls, dia. approx. 30 mm.



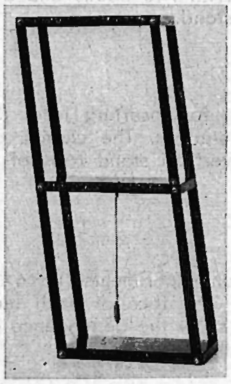
338 01 309 49

338 01

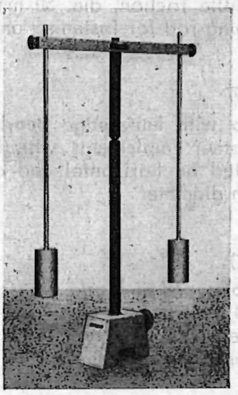
Plumb line, conical iron weight, 7 cm high, mass approx. 0.18 kg, with line.

309 49

Fishing line, 20 m, of finest raw silk, twisted, dia. approx. 0.5 mm, max. load: 4 kg.



338 31



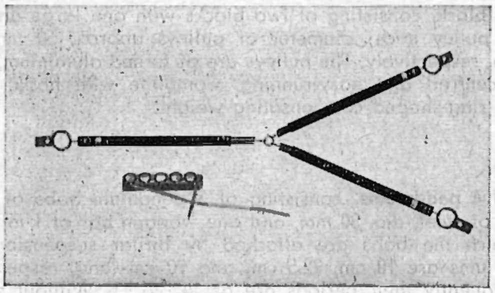
338 38

338 31

Stability apparatus, approx. 25 cm high, with easily recognisable position of centre of gravity which can be varied with relation to the supporting surface. In this manner stable and unstable equilibrium can be explained.

338 38

Equilibrium apparatus, approx. 25 cm high, for demonstrating stable, unstable, and neutral equilibrium. The system is supported at one point and the position of the centre of gravity can be varied. With base.

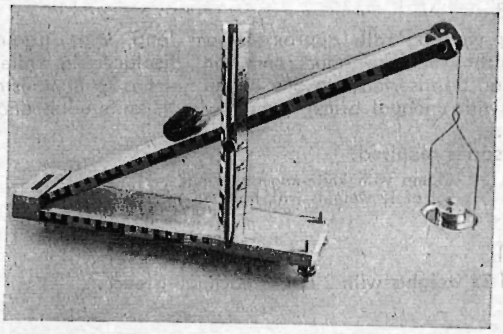


341 13

341 13

Set of spring balances for parallelogram of forces, according to Professor Maey, consisting of 3 spring balances without scales. These can be hooked into a ring to demonstrate the parallelogram of forces, or attached to a string to demonstrate the rope polygon. The ends of the spring balances can be attached to stands or pinned to the blackboard with drawing pins.
Complete set with ring, string and 5 large drawing pins, in cardboard box.

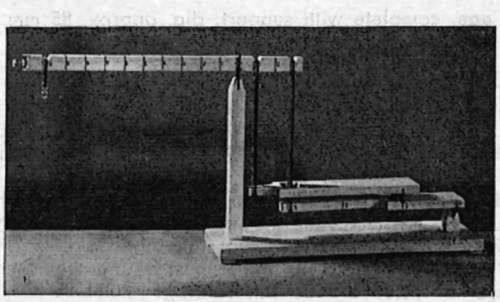
Strut-and-tie apparatus (343 60/61)
For descriptions and illustrations, please see appendix, pp. 202, 203.



341 21

341 21

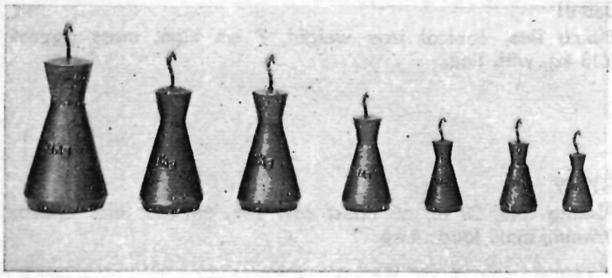
Inclined plane, 60 cm long, angle of inclination up to 40°, solid wooden construction with convenient coloured demonstration type graduations on the horizontal and vertical sides and on the inclined plane. The vertical side is, moreover, provided with an angle graduation divided in 5°.
Complete with guide pulley, roller, scale pan, levelling screws and string, but without weights.



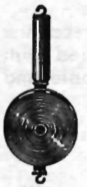
341 57

341 57

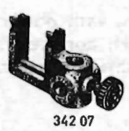
Model of a platform scale, length of weighing beam approx. 51 cm. A very clear model on which the transfer of forces by the weighing beam and the mode of action of the platform can be studied with ease.



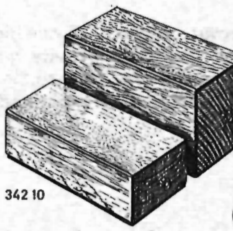
315 36



341 65



342 07



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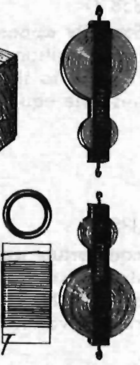
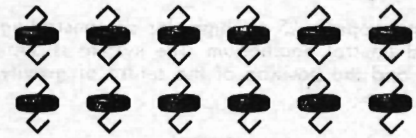
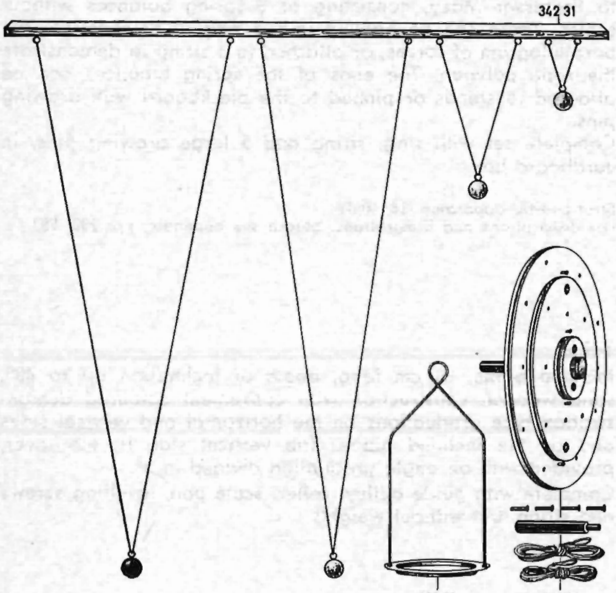


342 24



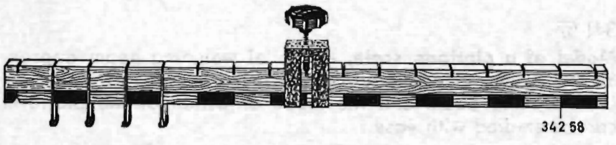
342 61



342 31

342 64

342 75



342 58

315 36

Set of 7 weights, of pleasing, modern shape, made of cast iron; each weight provided with a suspension hook and a transverse bar at the bottom for attaching further weights. The set is particularly convenient to handle in a great many experiments and comprises the following weights: 2 kg, 2×1 kg, 500 g, 2×200 g, 100 g.

341 65

Pulley, of turned aluminium, pivoted on one side only, runs with little friction, dia. 50 mm. With two hooks and a short clamping rod for fastening on a stand.

342 07

Clamp with knife-edge bearings, for inserting lever (342 58) and other implements with knife-edges. The clamp can be mounted on horizontal and on vertical stand rods of up to 12 mm diameter.

342 10

Pair of wooden blocks for friction experiments ($12 \times 6 \times 6$ cm^3 and $12 \times 6 \times 3$ cm^3, respectively); one face of each block is covered with plastic in order to show the dependence of the frictional force on the nature of the surface.

342 24

Pulley block, consisting of two blocks with one large and one small pulley each; diameter of pulleys approx. 50 mm and 25 mm, respectively. The pulleys are of turned aluminium, carefully centred and easy-running. Complete with hook, string and a ring-shaped compensating weight.

342 31

Set of 4 pendulums, consisting of 3 pendulum bobs of wood and 1 of steel, dia. 30 mm, and one wooden bar of 1 m length to which the bobs are attached by bifilar suspension. The pendulums are 10 cm, 22.5 cm, and 90 cm long, respectively. Consequently their periods are as $1/3 : 1/2 : 1$. Without stands.

342 58

Lever; wooden rail, approx. 50 cm long, with graduation, 17 notches to take riders and with displaceable knife-edge that can be inserted into one of the notches to demonstrate a lever with unequal arms; complete with knife-edge and four riders.

Accessories required:

Clamp with knife-edge bearings	342 07
Set of 12 weights with hook	342 61

342 61

Set of 12 weights with 2 hooks each, 50 g each.

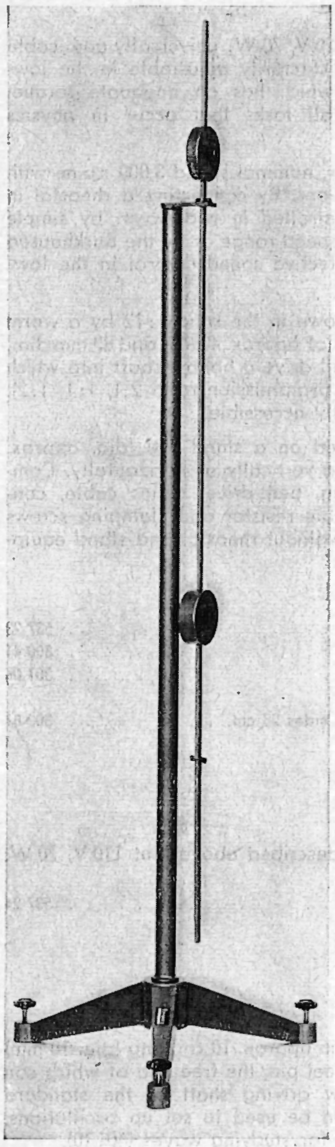
342 64

Scale pan, complete with support, dia. approx. 85 mm, 25 g.

342 75

Metal wheel and axle, light metal disc with 3 grooves of 25, 75, and 100 mm radius on one axle in ball bearings that can be inserted from either side, to demonstrate pulleys of different radii.

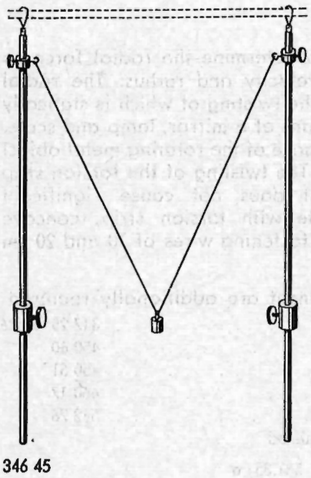
In order to demonstrate that a force may be applied anywhere along its line of action, the wheel is provided with four parallel rows of holes into which the pins supplied with the wheel may be inserted. The wheel must be mounted on stands that are not included under this catalogue number.



346 11

346 11

Reversible pendulum with support to determine the acceleration due to gravity. The apparatus consists of one rail 1.67 m long with two knives and two diplaceable and lockable metal discs as pendulum bobs and one high support with knife-edge bearings. It is easy to adjust by means of the levelling screws provided in the massive tripod. With suitable adjustment of the discs it is possible to obtain the same period of oscillation when using either of the knives. The knives are spaced 99.4 cm apart, so that the pendulum will oscillate as a seconds pendulum when properly adjusted. Overall height: approx. 1.85 m.



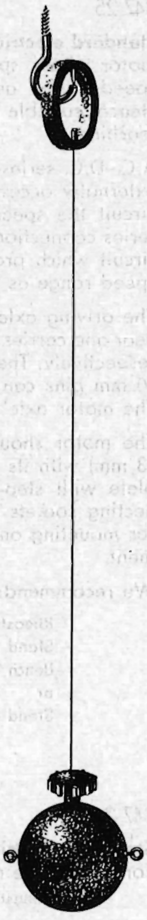
346 45

346 45

Double pendulum for demonstrating coupled oscillations. The apparatus consists of two adjustable pendulums with suspension hooks and hooks for coupling and a coupling weight. The periods of both pendulums are variable within wide limits.

With careful adjustment and 90° phase shift, the pendulum that is set oscillating will transfer its entire energy of oscillation to the second one which will then return it to the first.

The pendulums are each 85 cm long, of approx. 325 g mass. To be used on stand equipment.



346 39

346 39

Ball with pendulum suspension for Foucault's and other pendulum experiments, and for inertia experiments; ball, dia. approx. 60 mm, mass approx. 860 g; with string, knurled-head screw for attaching pendulum thread; the two eyes are required in inertia experiments. Pendulum suspension nearly frictionless; consists of a strong screw hook with bearing pan and a metal ring with a pointed steel pin and a hole for the pendulum thread. The screw hook is attached to the ceiling and the ball attached to the ring. Thereafter the steel pin is inserted into the bearing pan.

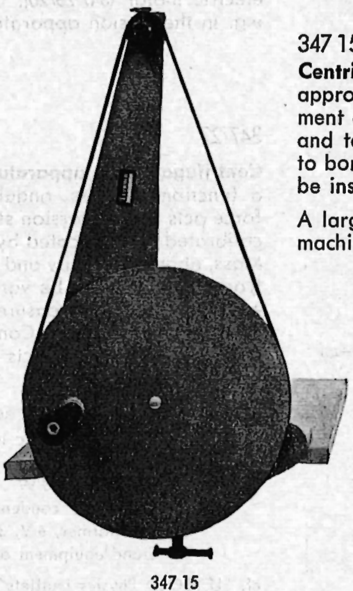
Detailed descriptions of pendulum experiments will be found in "LEYBOLD Physics Leaflets" DC 531.133.1; a / DC 531.211; a / DC 531.66; b / DC 531.662; b

Rotary motion

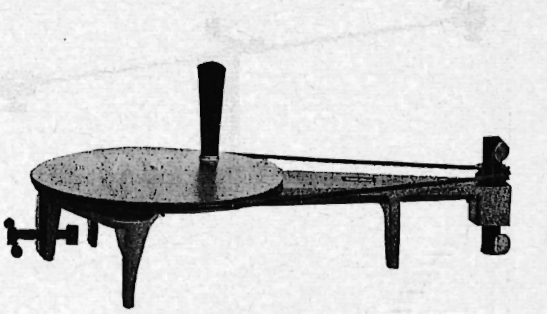
347 15

Centrifugal machine with belt drive. A massive appliance approx. 50 cm wide, with screw clamp for vertical arrangement and flywheel pulley (dia. approx. 25 cm) with hand crank and tensioning device for the driving belt. Transmission ratio to bored axle 1:7. Rods having a diameter of up to 10 mm can be inserted into the sleeve from either side and secured there.

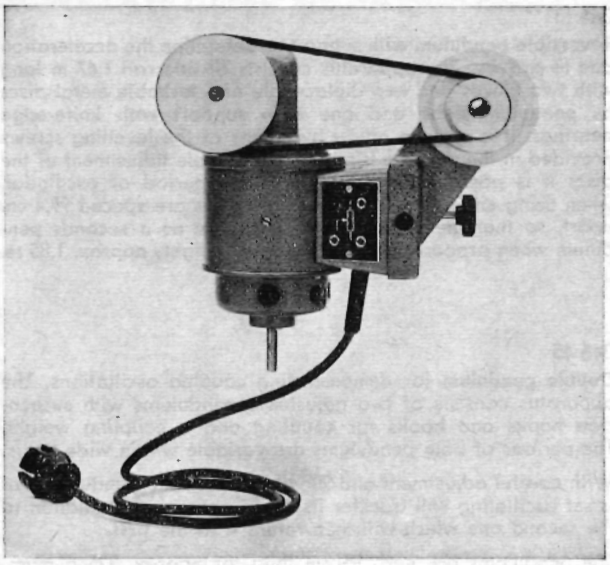
A large number of ancillary appliances render the centrifugal machine a highly versatile piece of equipment.



347 15
(with horizontal axis of revolution)



347 15
(with vertical axis of revolution)



347 25

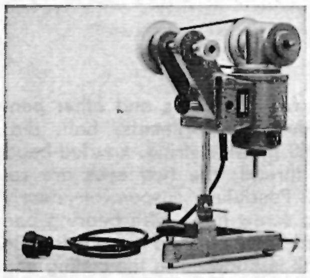


Fig. 12 PH 2010
Arrangement with horizontal axis

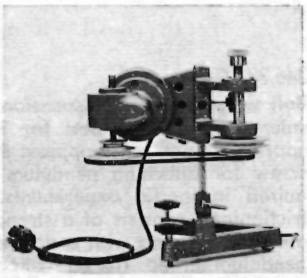
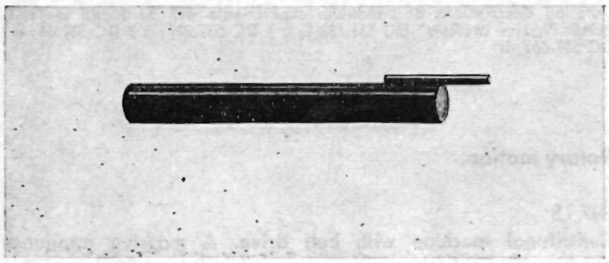
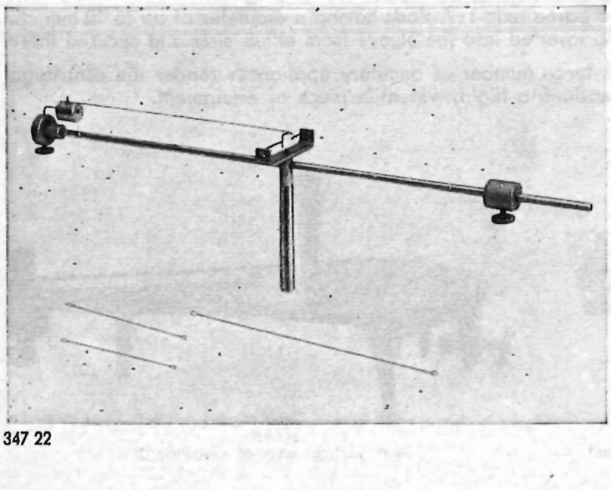


Fig. 13 PH 2011
Arrangement with vertical axis



347 28



347 22

347 25

Standard electric motor, for 220 V, 70 W; universally applicable motor whose speeds are satisfactorily adjustable in the low-speed range as well, and which has an adequate torque. Hence suitable for almost all tasks that occur in physics teaching.

A.C.–D.C. series-wound motor, nominal speed 3,000 r.p.m. with externally accessible connections. By connecting a rheostat in circuit the speed can be controlled in two ways: by simple series connection in the high-speed range or by the Barkhausen circuit which provides for effective speed control in the low-speed range as well.

The driving axle is geared down in the ratio 1:12 by a worm gear and carries 3 belt pulleys of approx. 40, 60, and 80 mm dia., respectively. These pulleys will drive a hollow shaft into which 10 mm pins can be clamped (transmission ratio 2:1, 1:1, 1:2). The motor axle is also directly accessible.

The motor should be mounted on a stand rod (dia. approx. 13 mm) with its axle arranged vertically or horizontally. Complete with step-down gearing, belt drive, mains cable, connecting sockets for the variable resistor and clamping screws for mounting on stands, but without rheostat and stand equipment.

We recommend:

Rheostat, 320 Ω	537 23
Stand rod	300 41
Bench clamp	301 06
or	
Stand base, length of sides 28 cm.	300 01

347 26

Standard electric motor, as described above, but 110 V, 70 W. For control we recommend:

Rheostat, 110 Ω	537 24

347 28

Eccentric attachment, metal pin approx. 10 cm long (dia. 10 mm) with eccentrically attached steel pin, the free end of which can be clamped into the hollow driving shaft of the standard electric motor (347 25/26). Can be used to set up oscillations, e.g. in the torsion apparatus for studying waves (401 10).

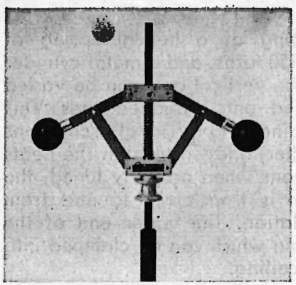
347 22

Centrifugal force apparatus, to determine the radial force as a function of mass, angular velocity and radius. The radial force acts upon a torsion strip the twisting of which is statically calibrated and indicated by means of a mirror, lamp and scale. Mass, angular velocity and distance of the rotating metal object from the centre can be varied. The twisting of the torsion strip occurring during measurement does not cause significant changes of distance. Complete with torsion strip, concave mirror, 2 revolving objects and fastening wires of 10 and 20 cm length, respectively.

The following pieces of equipment are additionally required:

Standard electric motor	347 25 or 26
Lamp house	450 60
Lamp, 6 V, 30 W	450 51
Single-lens condenser	460 17
Transformer, 6 V, 30 W	562 76
Stand equipment as required	

cf. "LEYBOLD Physics Leaflets", DC 531.35; a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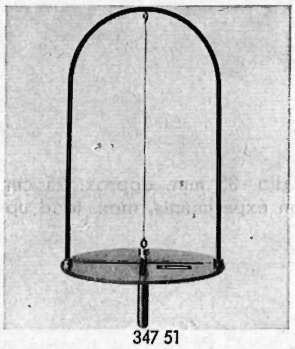
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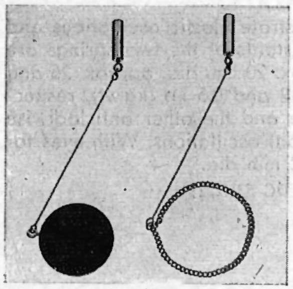
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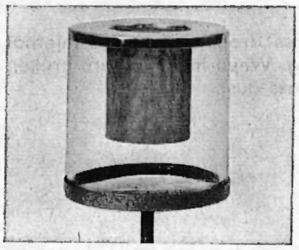
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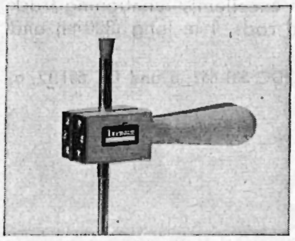
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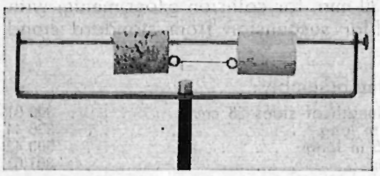
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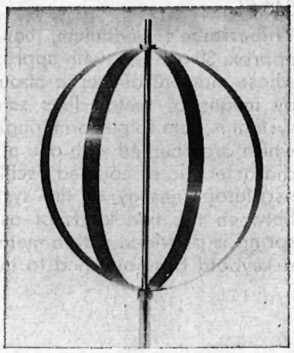
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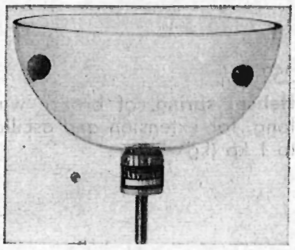
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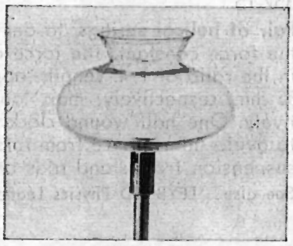
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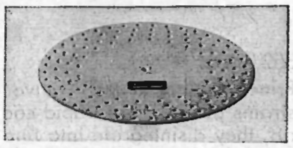
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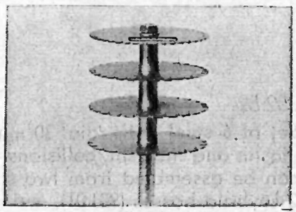
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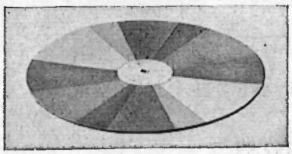

466 20

347 13

Ancillary equipment for the centrifugal force apparatus and the standard electric motor

The parts listed below are provided with 10 mm dia. pins for clamping them into the above apparatus.

347 37
Apparatus for demonstrating radially directed force. Two objects of unequal mass slide along a holder of approx. 25 cm length. They will only remain in equilibrium if the axis of rotation passes through their common centre of gravity.

347 45
Centrifugal governor, model, approx. 20 cm high.

347 48
Rings to illustrate the flattening of the earth at the poles. Two circular spring bows, dia. approx. 200 mm, whose planes are at right angles to one another, fixed at the bottom, sliding on top, on a vertical axle.

347 51
Rotatable pendulum, model of a Foucault pendulum, approx. 35 cm high. The plane of oscillation remains stationary if the assembly is turned slowly.

347 53
August's apparatus, glass hemisphere, dia. approx. 200 mm, with one wooden and one metal ball. Both balls will circulate at the same height, which depends upon the speed of rotation.

347 57
Rotatable glass vessel, dia. approx. 100 mm, shows the separation of non-miscible fluids (e.g. water and mercury) of different densities, due to centrifugal force.

347 60
Chain and disc, dia. approx. 60 mm, to demonstrate free axes and principal moments of inertia.

347 61
Model of centrifuge, dia. approx. 150 mm; glass vessel with gauze cylinder to demonstrate the function of a centrifuge.

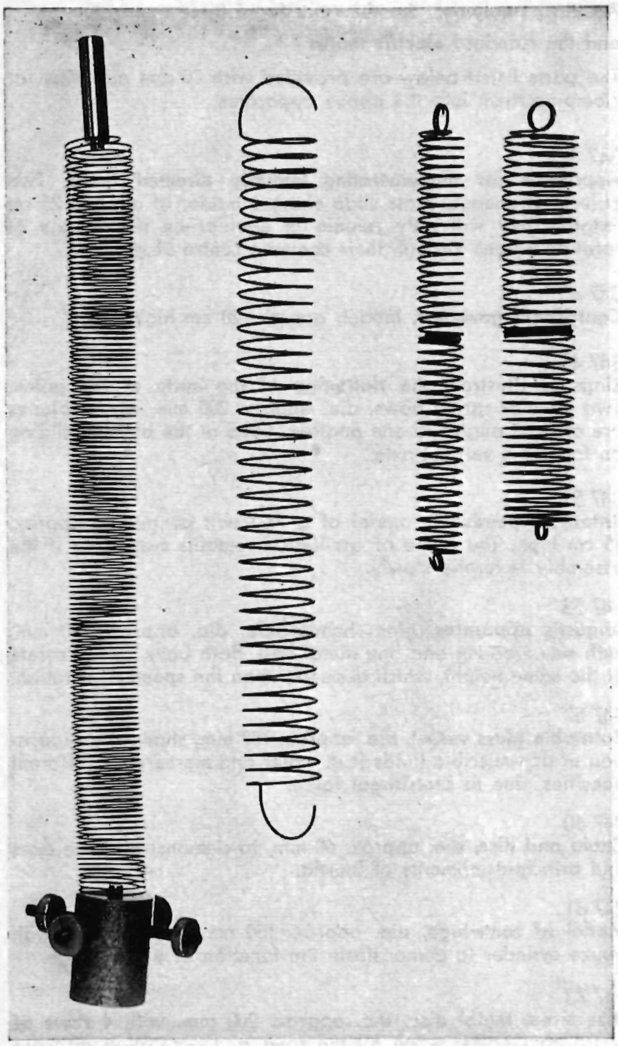
347 73
Disc siren, metal disc, dia. approx. 200 mm, with 4 rows of equidistant holes; when all the rows of the rotating disc are simultaneously blown with a blower (e.g. gas ballast pumps 104 10 S/110 00 S or 110 12 S/13 S), a major chord will be obtained; for use with the disc holder (347 13).

347 74
Savart's wheels, four metal discs (dia. approx. 70 mm) arranged one above the other a short distance apart on a common axle. When these are set in revolution and the edges are simultaneously touched with a sheet of cardboard or plastic, a major chord will be obtained.

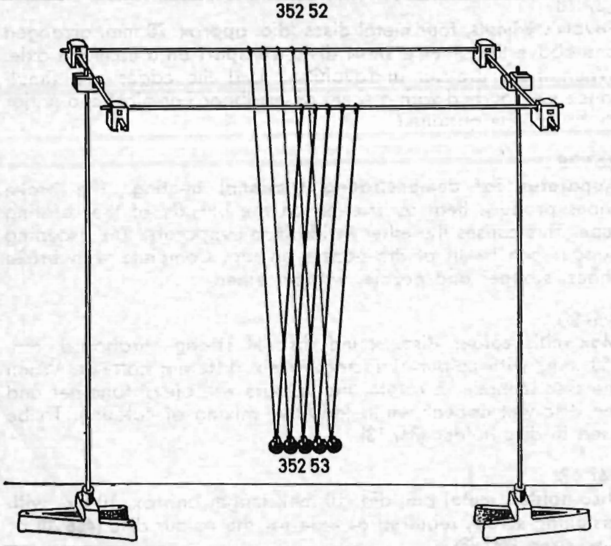
347 78
Apparatus for demonstrating frictional heating. The brake shoes produce heat by friction on the outside of the rotating tube. This causes the ether inside it to evaporate. The escaping vapour can be lit at the nozzle on top. Complete with brake shoes, stopper and nozzle, without ether.

466 20
Maxwell's colour disc, round disc of strong cardboard, dia. 250 mm; with coloured sectors in six different colours. When the disc is made to rotate, the colours will blend together and the disc will appear white (additive mixing of colours). To be used in disc holder (347 13).

347 13
Disc holder, metal pin, dia. 10 mm, length approx. 10 cm, with fastening screw, required as axle for the colour disc (466 20) or disc siren (347 73).


346 51 352 12 352 15

352 52



346 51

Wilberforce's pendulum, consisting of a helical spring of approx. 30 mm dia. with approx. 150 turns, and a metal cylinder whose moment of inertia about the vertical axis can be varied by means of metal discs screwed onto threaded rods. This system is able to perform longitudinal and torsional oscillations which are coupled with one another, and will exhibit the beats characteristic of coupled oscillations when properly tuned: the oscillatory energy of the system is transferred to and from between the two kinds of oscillation. The upper end of the spring is provided with a metal pin which can be clamped into a Leybold boss attached to the ceiling.

352 12

Helical spring, of bronze wire, dia. 35 mm, approx. 25 cm long, for extension and oscillation experiments, max. load up to 1 kp (kg wt).

352 15

Pair of helical springs, to demonstrate elastic oscillations and the force constant. The force constants of the two springs are in the ratio of 1:4. Length: approx. 20 cm, dia. approx. 25 and 35 mm, respectively; max. loads 2 and 0.5 kp (kg wt), respectively. One half wound clockwise and the other anticlockwise to avoid interference from torsional oscillations. With eyes for suspension from stand rods of 12 mm dia.

See also: "LEYBOLD Physics Leaflet", DC 531.222; a.

352 01

Prince Rupert drops. Twelve glass drops with large internal strains produced by rapid cooling. When their tips are broken off, they disintegrate into fine glass dust.

352 52

Set of 6 steel balls, dia. 30 mm, especially for experiments on elastic and inelastic collisions. An excellently-functioning track can be assembled from two stand rods, 1 m long (300 44) and 2 Leybold bosses (301 01).

See also: "LEYBOLD Physics Leaflets", DC 531.662; a and DC 531.12; a.

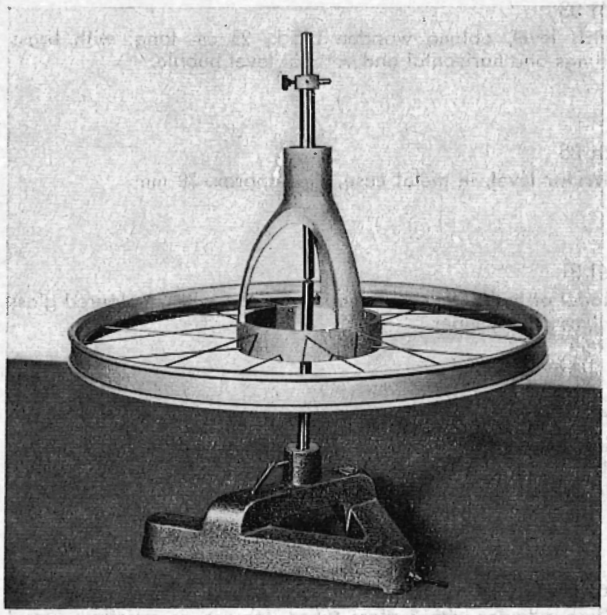
352 53

Set of 5 steel balls, dia. 30 mm, for collision experiments; with eyes and strings for bifilar suspension from standard stand equipment.

Recommended parts for the assembly:

2 Stand bases, length of sides 28 cm	300 01
4 Stand rods, 1 m long	300 44
2 Stand rods, 0.5 m long	300 42
6 Leybold bosses	301 01

See also: "LEYBOLD Physics Leaflets", DC 531.661; a and DC 531.662; a.



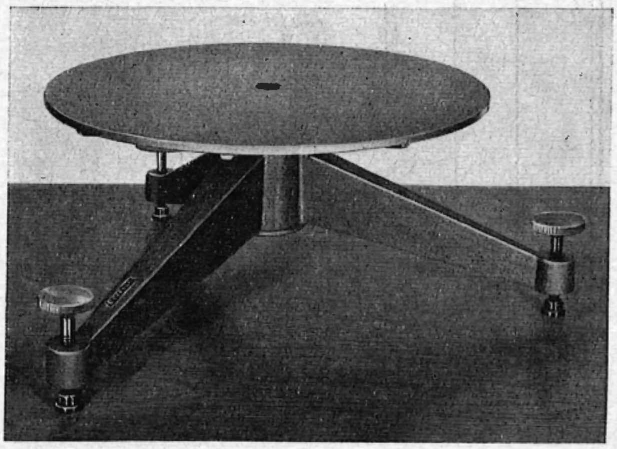
348 18

331 69

Stool, to be screwed to Prandtl's rotatable disc (331 66). Experiments with the rotatable disc are easier and more convenient to perform if the experimenter is sitting.

The stool consists of a steel-plate frame with 3 legs and a round, polished hardwood seat, dia. approx. 40 cm; overall height approx. 48 cm.

The holes for screwing the stool to the rotatable disc are drilled by us if required. Three fastening screws are supplied with the stool.



331 66

348 18

Large gyroscope, for explaining all important laws of gyroscopic motion and such concepts as: gyroscope acted on by no external forces, axis of symmetry, instantaneous axis of rotation, precession, nutation and, in combination with Prandtl's rotatable disc, for experiments on angular momentum.

Carefully balanced bicycle wheel (dia. approx. 50 cm) with large moment of inertia; hub bee-hive-shaped, with ball bearings. In this manner it becomes possible to displace the shaft, during rotation, in such a manner that the point of support is either below, at, or above the centre of gravity.

Complete with 1 stand base, one rod with hardened point and one with hardened bearing pan, each approx. 25 cm long, and one 50 cm long rod for the experiments on angular momentum.

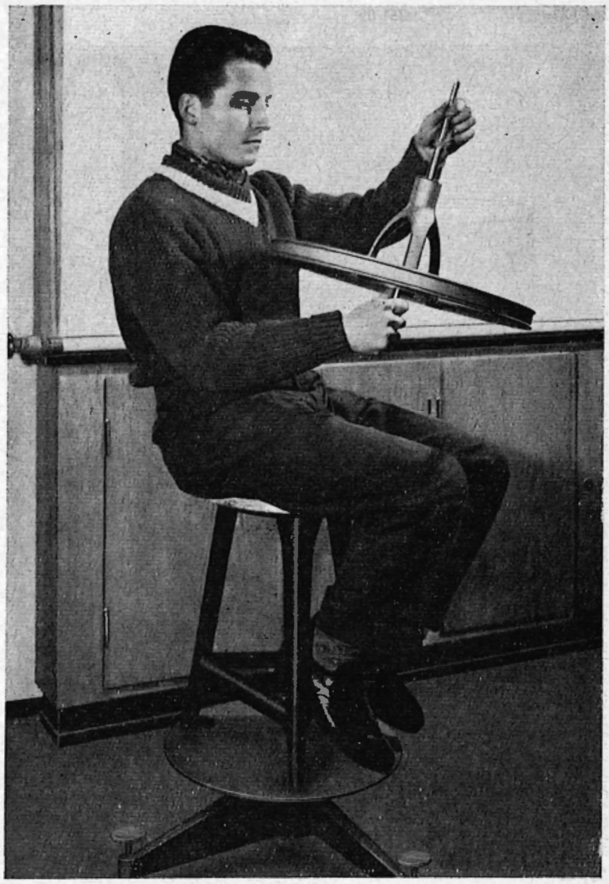


Fig. 14 PH 2012

Experiments with the large gyroscope (348 18) on Prandtl's rotatable disc with stool (331 66 and 331 69).

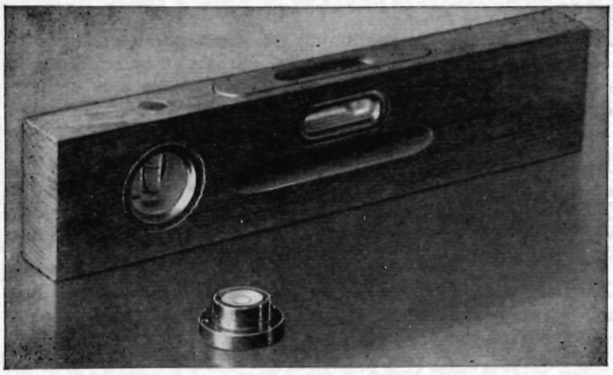
331 66

Prandtl's rotatable disc, to explain moment of inertia, angular momentum and the laws connecting them.

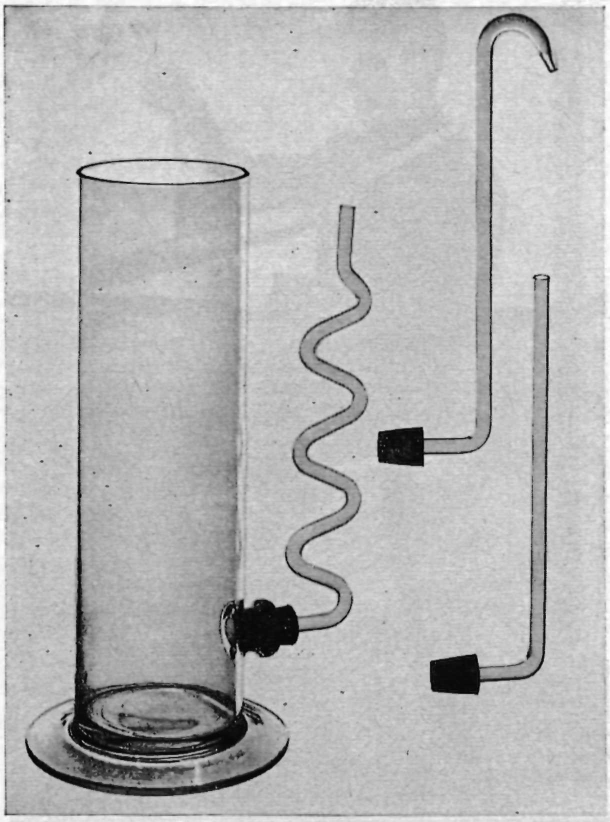
Robust metal disc, dia. approx. 45 cm, with axle in ball bearings, on massive tripod with levelling screws; height approx. 30 cm, mass approx. 17 kg. The rotatable disc can also be used in all experiments where easy and troublefree rotation is desired.

We recommend the following additional equipment for the experiment:

Stool	331 69
Large gyroscope	348 18
2 Stand bases	300 01
or	
1 Pair of dumbbells	



361 03 361 05



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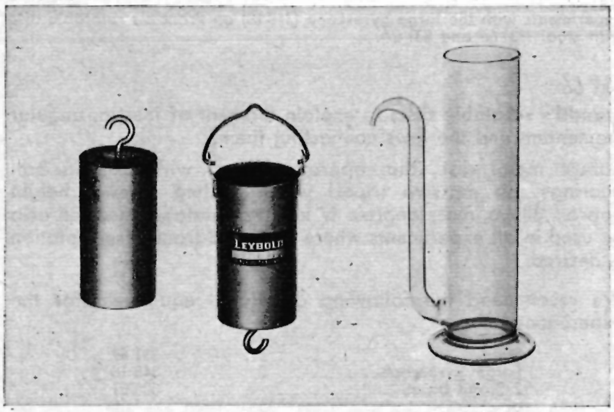


362 01 362 04

361 03
Spirit level, oblong wooden block, 25 cm long, with brass fittings and horizontal and vertical level bubble.

361 05
Circular level, in metal case, dia. approx. 30 mm.

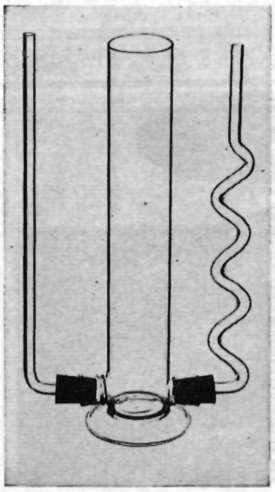
361 31
Model of hydraulic press, made of glass, with 2 coloured glass valves and cylinder.

361 41
Liquid level apparatus, glass cylinder with 2 differently shaped glass tubes for insertion into the openings at the bottom. Height: approx. 22 cm.

361 44
Glass cylinder with 3 glass tubes, for use as overflow vessel and to demonstrate connected tubes. The glass cylinder is approx. 30 cm high, dia. approx. 90 mm, with opening for alternative insertion of variously shaped glass tubes. Complete with cylinder, overflow tube, straight and corrugated tubes and rubber stoppers with holes.

362 01
Archimedes' cylinder, consisting of a precisely made, beaker-shaped cylinder with carrier strap and hook and a closely fitting hollow cylinder with eye, all made of brass, plated with a thick nickel coat. For use on the hydrostatic balance to verify Archimedes' principle. Height without strap: approx. 7 cm.

362 04
Overflow vessel, glass cylinder, approx. 15 cm high, dia. approx. 40 mm, with upward-bent discharge tube ending in a narrow spout; for exact determinations of volume.



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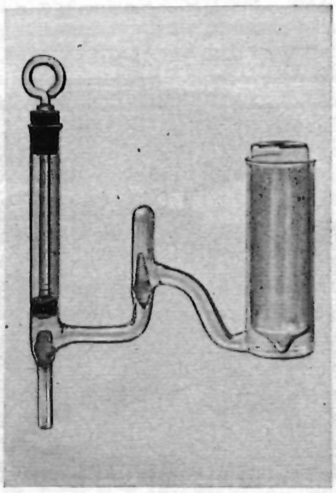

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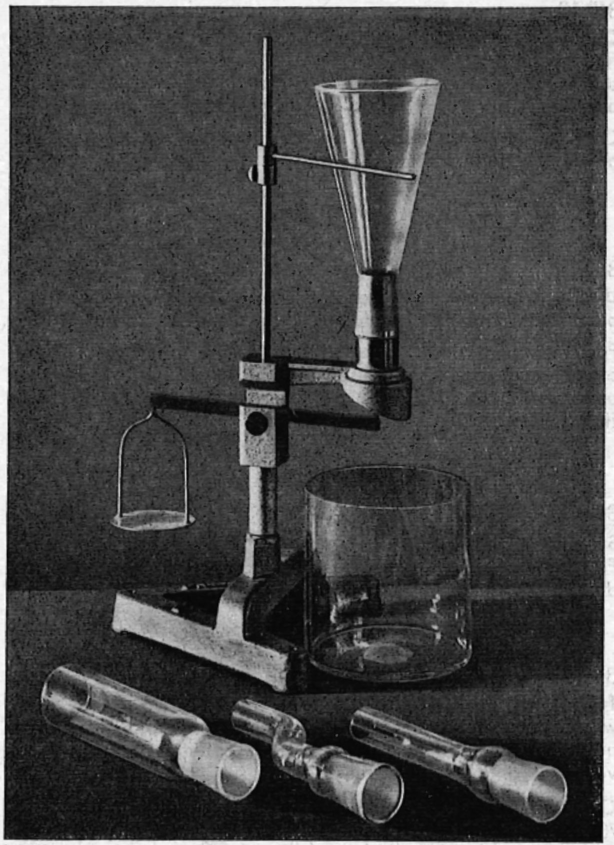


361 49

361 24

Apparatus for demonstrating the transmission of pressure in liquids, approx. 30 cm high. When the plunger is pressed down, the liquid will rise equally high in the 5 glass tubes that branch off from the bulb in various directions Complete with plunger, plug and glass tubes.

361 49

Pascal's vane apparatus, for direct demonstration of the hydrostatic paradox, improved design. Instead of the plate used by Pascal, an exactly fitting plunger here brings about a complete seal until the pressure of the water introduced into the vessel exceeds the critical pressure, when the plunger will open instantaneously.

The precise engineering, especially the balance beam resting on points, renders the apparatus very sensitive for this striking experiment.

Variously shaped glass parts with standard ground joints can be arranged on the metal male ground joint in turn, and filled with water.

Complete with: stand, scale pan, water level indicator, 4 glass vessels and large beaker to receive outflowing water; overall height approx. 45 cm.

361 56

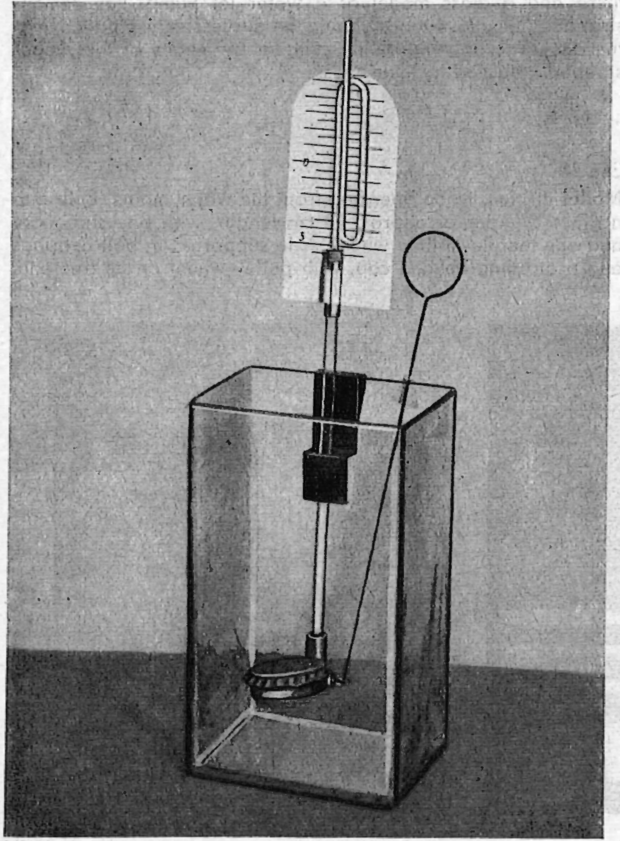
Liquid-pressure gauge. Experiments with this apparatus show that the pressure within a liquid rises linearly with depth and is independent of direction.

Aneroid capsule (dia. approx. 60 mm) sealed on one side only by a membrane, connected to a manometer by a 30 cm long glass tube.

The device can be moved up and down in the glass cell supplied with it, manipulating it by the handle; the aneroid capsule is provided with an eye and can be turned under water by means of a hook.

361 61

Buoyancy apparatus, glass cylinder, 22 cm high, dia. approx. 45 mm, and aluminium plate with cord. The plate is held against the lower opening of the cylinder by means of the cord till the tube is under water. The plate will then be firmly pressed against the lower opening by the water and only fall off when the cylinder is filled with liquid.



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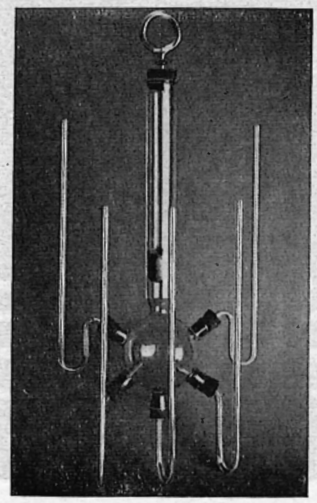

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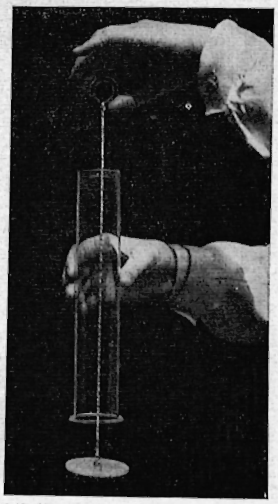


361 61

362 13

Cartesian diver, hollow figure made of coloured glass with one fine opening, will float upright in a water-filled glass cylinder and may be caused to rise, sink, or turn by varying the pressure of the thumb against the stopper of the glass tube.

Complete with diver, glass cylinder (approx. 32 cm high, dia. approx. 40 mm) and rubber stopper.

362 41

U-tube with scale, U-shaped glass tube mounted on a wooden panel with two coloured scales. Overall height approx. 60 cm.

For comparing the densities of liquids. After pouring in, liquids of different density will rise to a different height in the two arms of the glass tube. Use a barrier fluid to separate miscible fluids.

362 23

Set of 5 metal cubes, in wooden box. One cube each of Al, Pb, Fe, Zn, and brass; length of sides 10 mm precisely; for direct determination of the densities of these substances.

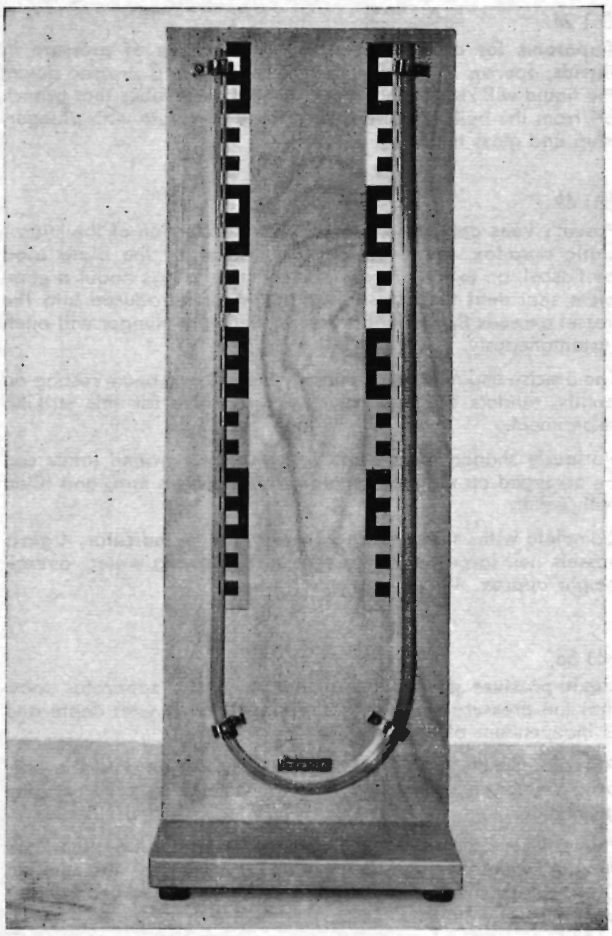
366 12

Tubes with reservoir, to study the pressure variations when water flows through tubes of various widths. The pressure is indicated by the height of the water columns in the various vertically attached glass tubes.

Complete with glass cylinder (approx. 40 cm high, dia. approx. 70 mm) with discharge opening, 3 glass tubes of differing widths with vertically attached gauge tubes, one wooden support for these and a glass model of a water jet pump. For demonstrations, the glass tubes should be successively plugged into the discharge opening of the cylinder by means of the rubber stoppers attached to their ends.

366 44

Model turbine, to be operated from the water mains; built into a glass cylinder of approx. 25 cm length, with one stationary and one mobile turbine wheel. Axle supported in ball bearings and protruding beyond cap, with pulley wheel on its free end.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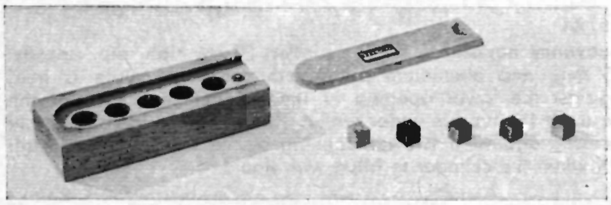
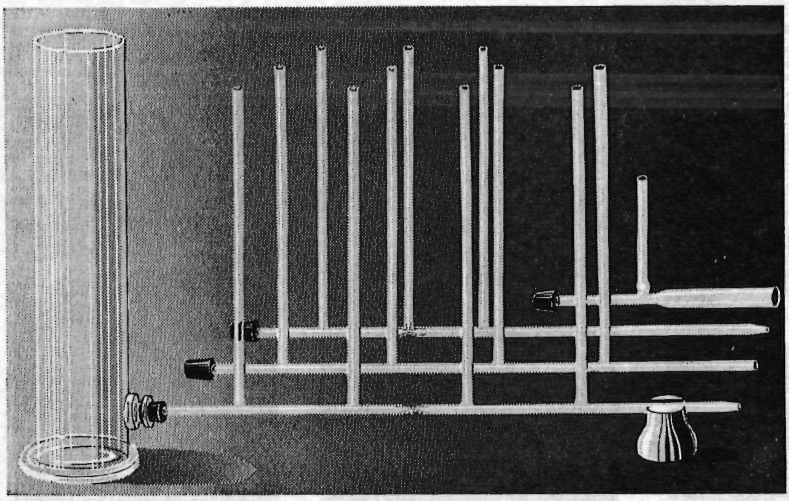

362 23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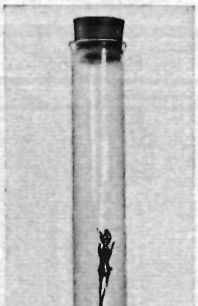
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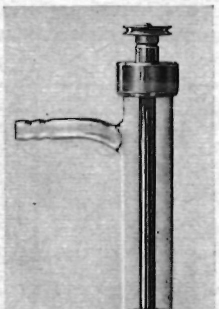
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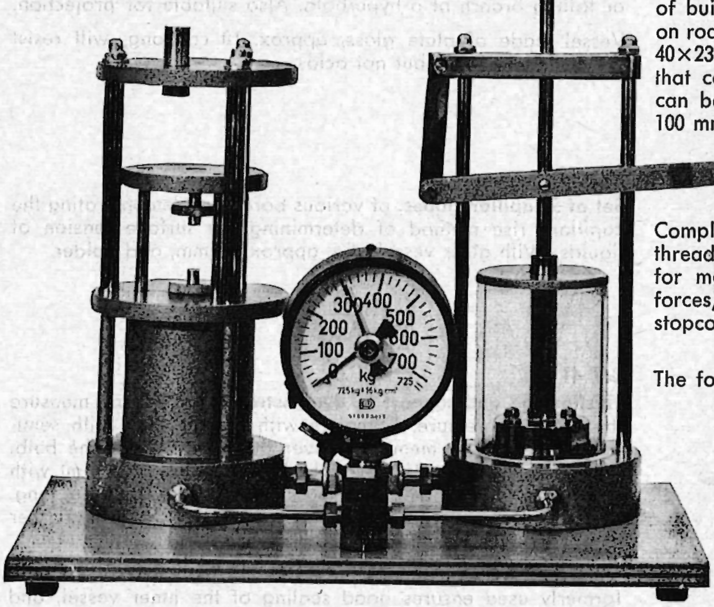


361 10

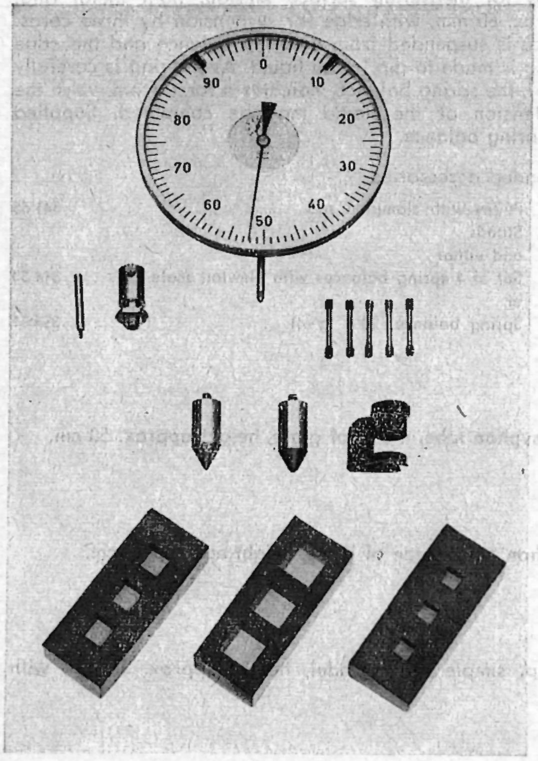
361 10

Hydraulic press, for demonstration of hydraulic force transmission. Suitable for compression and tension. The most important material testing processes can be demonstrated on this model, with numerically significant results: compression strength of building materials, hardness of materials and tensile tests on rods. Made of metal, mounted on strong base plate (approx. 40×23 cm^2), mechanical advantage 1:100. The maximum force that can be produced is 725 kp (kg wt). The forces produced can be read on a manometer calibrated in kg (dia. approx. 100 mm).

Complete with stationary supports for tension and compression, thread for screwing in Brinell hardness test balls and device for mounting tensile test specimen, manometer for reading forces, oil filling (approx. 1000 cm^3), oil return conduit and stopcock.

The following accessories are recommended:

Dial gauge	361 15
Set of tensile test specimens	361 12
Steel balls for Brinell hardness testing, and simple microscope with scale	361 13
Set of cubical moulds	361 14



361 15

361 12

361 13

361 14

361 12

Set of tensile test specimens, suitable for recording tension-extension diagrams and to determine the breaking strain. Consists of one rod each of chromium-vanadium steel, automatic steel, brass, copper, and aluminium; length approx. 35 mm, dia. approx. 3 mm, with M 5 thread at either end for screwing into the hydraulic press.

361 15

Dial gauge, shockproof, accessory to the hydraulic press, for measuring the extension of test pieces when recording tension-extension diagrams, and for determining the breaking strain.

Scale diameter 140 mm, with revolving hand, 1 mm lift per revolution, graduated in $^1/_{100}$ mm, total lift 10 mm.

361 13

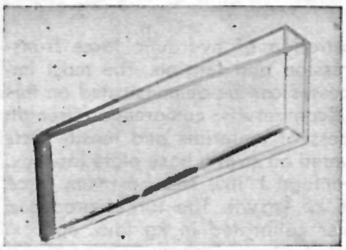
Steel balls for Brinell hardness testing and simple microscope with scale. 2 hardened steel balls, dia. 2.5 and 5 mm, respectively, for determining the hardness of metal plates with the hydraulic press. The balls are mounted in holders that can be screwed into the hydraulic press. With magnifying lens, 8-fold magnification, on stand, with 5 mm measuring edge graduated in $^1/_5$ mm to determine the diameter of the hemispherical indentations produced in the material.

361 14

Set of cubical moulds, for making test cubes of plaster, concrete, and so on, to compare compression strengths with the hydraulic press.

The test cubes can be used to study the influence of the composition of the materials used, ageing, and of the size of the cube upon the compression strength.

The set consists of 3 moulds for 3 cubes each of 1 cm^2, 2 cm^2, and 4 cm^2 face area. The moulds are made of a very constant-shape, but flexible material, and the specimens are, therefore, easy to take out.



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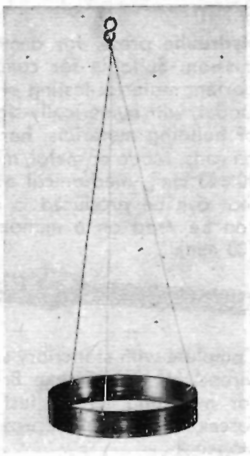

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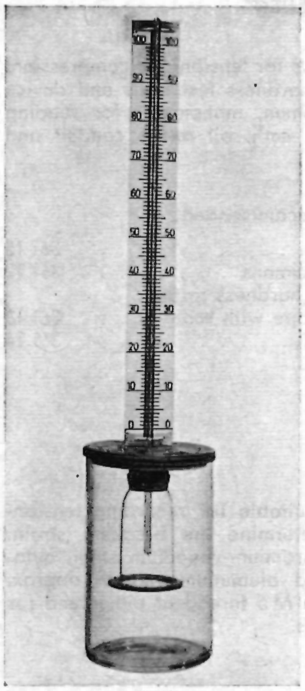

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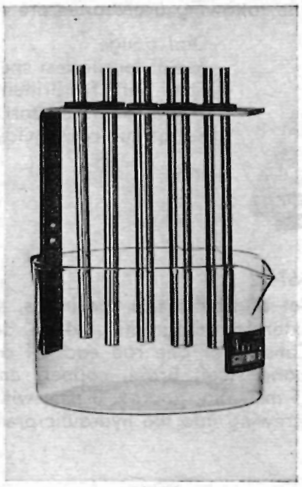
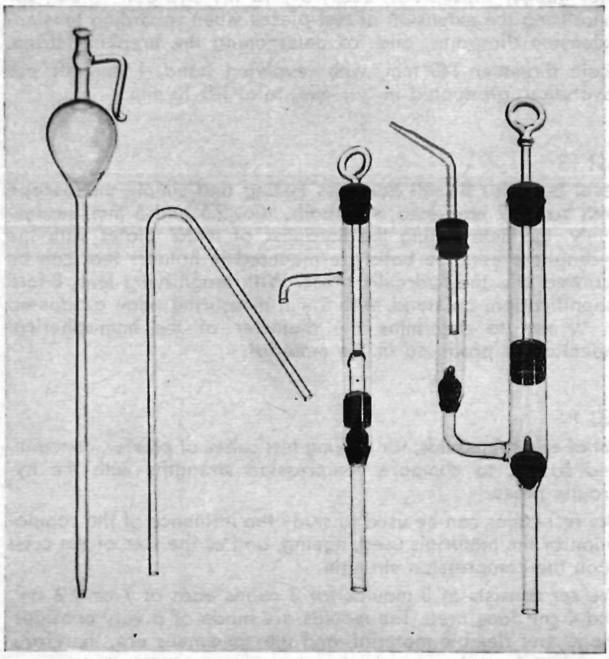


367 16



371 12 371 13 375 06 375 11

367 14

Wedge-shaped glass vessel, for demonstrating capillary action. Wetting liquids will rise in the acute-angled end, non-wetting ones will be forced out of it; in agreement with theory the curve in which the liquid surface cuts the glass wall is a rising or falling branch of a hyperbola. Also suitable for projection.

Vessel made of plate glass, approx. 10 cm long, will resist water and solvents, but not acids.

367 16

Set of 5 capillary tubes, of various bores, for demonstrating the capillary rise method of determining the surface tension of liquids. With glass vessel, dia. approx. 95 mm, and holder.

367 41

Thistle tube and support to demonstrate osmosis and measure the osmotic pressure. Complete with: Thistle tube with semipermeable plastic membrane over the open end of the bulb, glass cylinder (approx. 13 cm high, dia. approx. 80 mm) with wooden lid with hole, and glass tube, approx. 40 cm long, permanently mounted on a metal scale, as well as rubber stopper with hole.

The use of a plastic membrane instead of the animal membrane formerly used ensures good sealing of the inner vessel, and rotting is impossible.

367 46

Apparatus for measuring surface tension, light metal ring, dia. approx. 60 mm, with edge for suspension by three cords. The device is suspended from a spring balance and the edge of the ring is made to dip into a liquid. As the ring is carefully drawn out, the spring balance indicates a force from which the surface tension of the liquid may be computed. Supplied without spring balance.

Recommended accessories:

Pulley with clamping rod	341 65
Stands	
and either	
Set of 4 spring balances with Newton scale	314 30
or	
Spring balance, 10 p (g wt)	314 11

371 12

Straight syphon tube, made of glass, height approx. 50 cm.

371 13

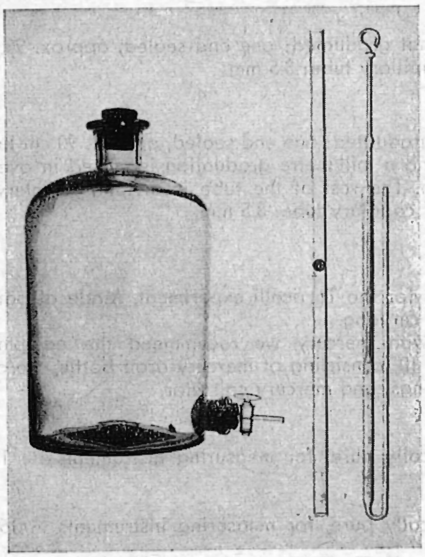
Bent syphon tube, made of glass, height approx. 30 cm.

375 06

Lift pump, simple glass model, height approx. 35 cm, with 2 valves.

375 11

Force pump, glass model, height approx. 40 cm, with 2 valves.



371 04 371 05 371 52

371 04

Aspirator, capacity approx. 10 l, with wide neck and discharge opening at the bottom, 2 rubber stoppers with holes and one glass stopcock.

For use with the apparatus for c_p/c_v determination (371 05).

371 05

Apparatus for determining the ratio of the specific heats c_p/c_v, according to Rüchard; also suitable for experiments on the viscosity of gases. Precision-ground glass tube, approx. 60 cm long, with exactly fitting steel ball.

If this tube is fitted on the aspirator bottle, the ball released at the upper end of the glass tube will oscillate on the enclosed air cushion. By an easily derived formula the ratio of the specific heats c_p/c_v can be determined with considerable accuracy from the period of the oscillations and the apparatus constants.

For this experiment the aspirator bottle (371 04) is needed.

371 52

Boyle's law apparatus, simple design, height 40 cm, range of pressure approx. 760 to 1,000 mm Hg. Approx. 350 g of mercury are required.

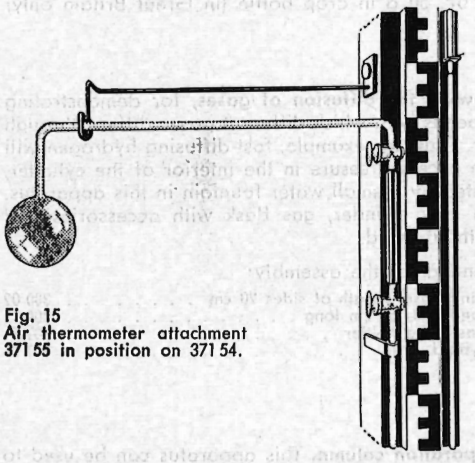
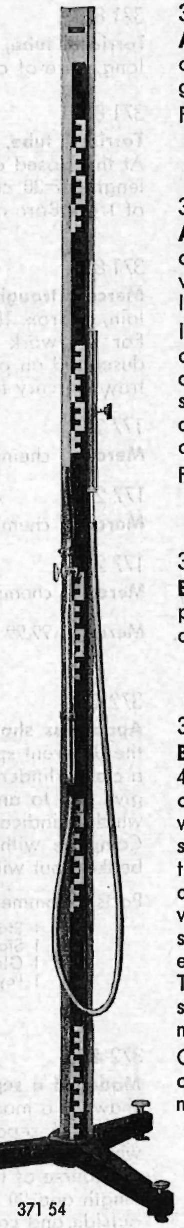


Fig. 15
Air thermometer attachment 371 55 in position on 371 54.



371 54

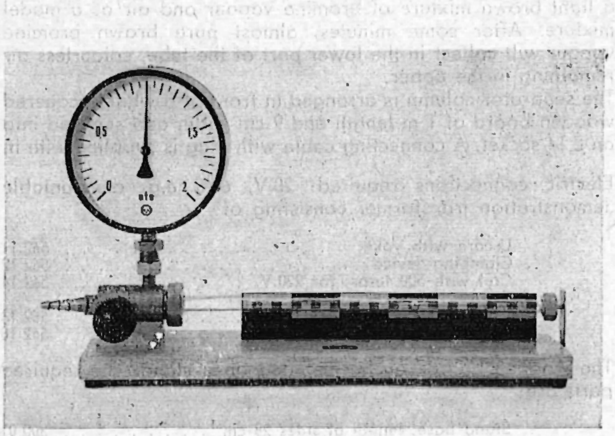
371 54

Boyle's law apparatus, large design, range of pressure approx. 400 to 1,500 mm Hg. The apparatus is mounted on a column with coloured scale of approx. 2 m length. On one side a glass tube with stopcock is permanently mounted. On the other side, a second glass tube can be displaced along the entire length of the scale and locked in any desired position. These glass tubes are connected by means of PVC pressure tubing, which is filled with mercury. By lifting and lowering the movable tube the space below the cock, in which a certain volume of air is enclosed, can be subjected to increased or reduced pressure. The length of the enclosed air column of constant cross-sectional area is read. The apparatus can also be used to measure the atmospheric pressure.

Complete with stand base with levelling screws, without mercury. Requires approx. 2 kg of mercury for filling. An air thermometer attachment can be obtained separately (371 55).

371 55

Air thermometer attachment, for use with Boyle's law apparatus (371 54); consists of a bulb with attached capillary tube, stopcock and holder. The capillary tube is connected to the Boyle's law apparatus (371 54), and the bulb is then heated in a water bath. The volume is kept constant by raising the mercury level, and the pressure is then read.



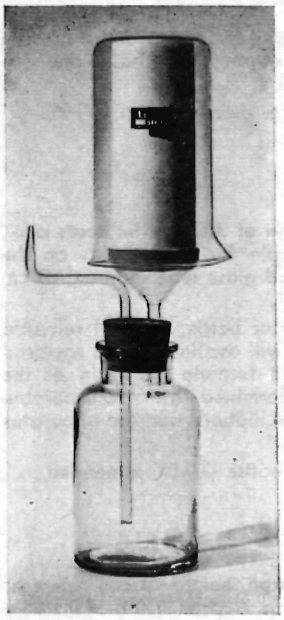
371 57

371 57

Boyle's law apparatus, Kröncke design; the apparatus does not require mercury. It consists of a precision-ground glass tube with exactly fitting ball which blocks the volume to be measured. The pressure can be adjusted in the range 0 to 2 atmospheres by means of a needle valve, and read on a manometer.

Mounted on base board, with scale (30 cm long), needle valve, manometer and hose nipple, but without pump and hose.

We recommend using a force pump, e.g. gas ballast pump D 2 (110 12 S or 110 13 S) and pressure tubing (412 73).



372 43

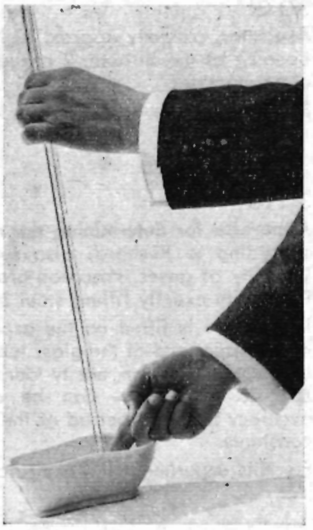


Fig. 16 PH 2013
How to introduce a filled Torricelli tube (371 81/82) into the mercury trough.

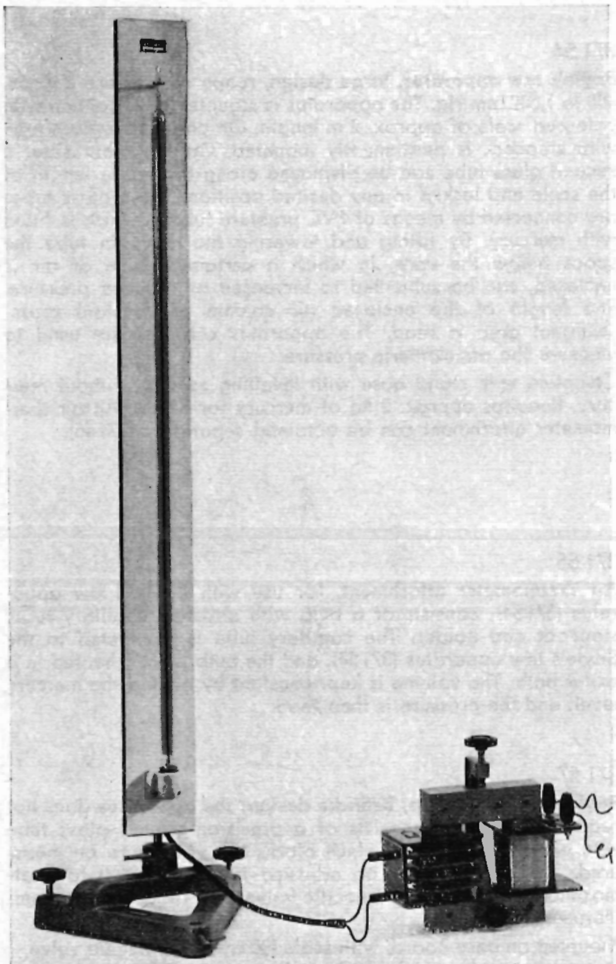


Fig. 17 PH 2014
Model separator tube (372 45) on stand (300 01/300 44) with demountable demonstration transformer (562 11/12/14/18) as source of current.

371 81

Torricelli tube, not graduated; one end sealed, approx. 90 cm long, bore of capillary tube: 3.5 mm.

371 82

Torricelli tube, graduated; one end sealed, approx. 90 cm long. At the closed end a millimetre graduation is etched in over a length of 30 cm. The rest of the tube is divided at intervals of 1 cm. Bore of capillary tube: 3.5 mm.

371 85

Mercury trough, for the Torricelli experiment. Made of porcelain, approx. 18 cm long.
For all work with mercury we recommend the equipment described on p. 10, consisting of mercury drop bottle, mercury tray, mercury tongs, and mercury collector.

177 21

Mercury, chemically pure, for measuring instruments 1 kg

177 23

Mercury, chemically pure, for measuring instruments 150 g

177 24

Mercury, chemically pure, for measuring instruments 50 g

Mercury, 99.99 BP, 50 g in drop bottle (in Great Britain only)

372 43

Apparatus showing the diffusion of gases, for demonstrating the different speeds with which different gases diffuse through a clay cylinder. Thus, for example, fast-diffusing hydrogen will give rise to an excess pressure in the interior of the cylinder, which is indicated by a small water fountain in this apparatus. Complete with clay cylinder, gas flask with accessories and beaker, but without stand.

Parts recommended for the assembly:

1 Stand base, length of sides 20 cm	300 02
1 Stand rod, 50 cm long	300 42
1 Glass tube holder	301 71
1 Leybold boss	301 01

372 45

Model of a separation column. This apparatus can be used to show on a model the thermal diffusion effect and the mode of action of separator columns for isotopic mixtures, processes which have only come to be treated in schools and colleges in the course of the last few years. A glass tube of approx. 80 cm length and 20 mm diameter is cooled by the ambient air from outside and contains a second glass tube, coaxial with it, with a heating filament. The space between the glass tubes contains a light brown mixture of bromine vapour and air as a model mixture. After some minutes, almost pure brown bromine vapour will collect in the lower part of the tube, colourless air remaining in the upper.
The separator column is arranged in front of a white lacquered wooden board of 1 m length and 9 cm width and screwed into an E 14 socket. A connecting cable with plug is supplied with it.

Electric connections required: 20 V, 6 A, e.g. demountable demonstration transformer consisting of:

U-core with yoke	562 11
Clamping device	562 12
Coil with 500 turns, for 220 V	562 14
or	
Coil with 250 turns, for 110 V	562 13
Coil with 46 turns	562 18

The wooden board can be mounted on a stand. The required parts are:

Stand base, length of sides 28 cm	300 01
Stand rod, 1 m long	300 44

376 01

Model experiment on the kinetic theory of gases, for illustrating the thermal motion of molecules and atoms in a gaseous mixture exposed to the influence of the gravitational field of the earth, and to demonstrate the transformation of a gas into the liquid and, ultimately, the solid state.

Colourless and coloured glass beads of 5–10 mm diameter form the "model gas". These can be set in more or less vigorous motion in a glass cylinder mounted vertically on an oscillating system with electromagnetic excitation. The oscillating system is tuned to a natural frequency of 100 c/s and is set oscillating by a field that alternates with the mains frequency.

The glass cylinder, dia. approx. 65 mm, height 40 cm, is closed with a transparent plastic lid. The pole pieces of the apparatus are mounted on the plane ground top faces of the arms of the U-core of our demountable demonstration transformer wired up as an electro-magnet, and retained there by means of the clamping bows supplied with it.

For better visibility the tube should be illuminated from above.

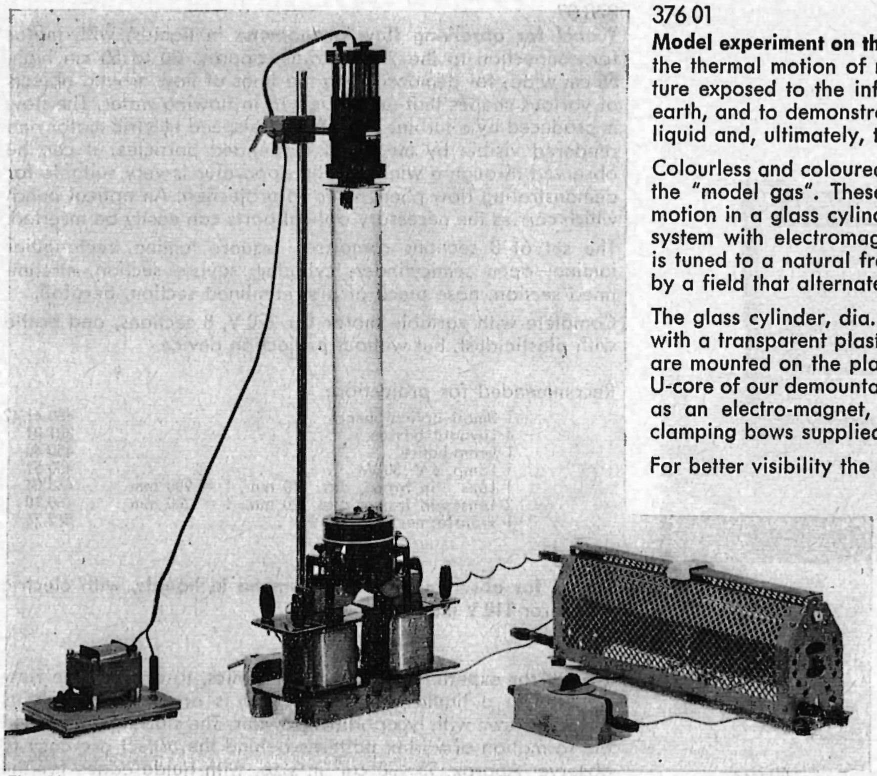


Fig. 18 PH 2015

Fig. 18
Model experiment on the kinetic theory of gases, experimental arrangement.

As illuminating device we recommend:

Lamp-house	450 60
Lamp, 6 V, 30 W	450 51
Single-lens condenser	460 17
Stand base, length of sides 20 cm	300 02
Stand rod, 75 cm long	300 43
Leybold-boss	301 01
Transformer, 6 V, 30 W	562 76

For the electromagnet the following parts of the demountable demonstration transformer are required:

U-core	from 562 11
For 220 V mains voltage, 50 c/s *)	
2 Coils with 500 turns	562 14
Rheostat, 320 Ω	537 23
For 110 V mains voltage, 50 c/s *)	
2 Coils with 250 turns	562 13
Rheostat, 110 Ω	537 24

*) The apparatus is unsuitable for 60 c/s mains.

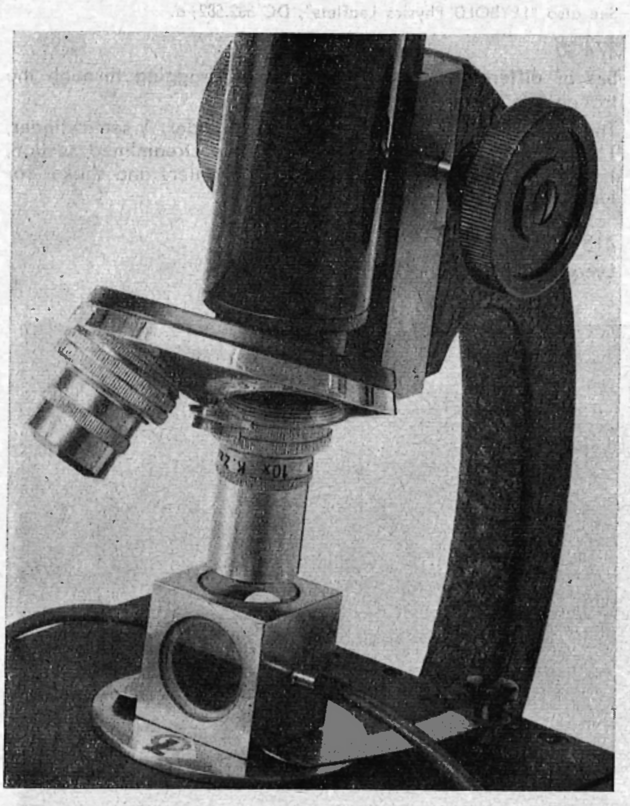
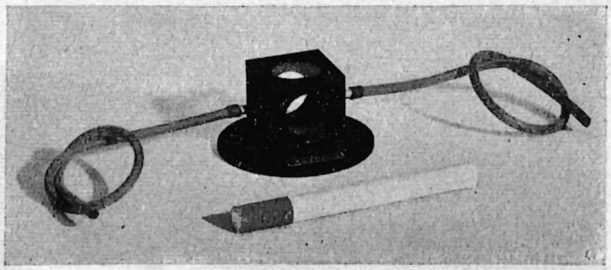


Fig. 19 PH. 2016
Observation of Brownian motion in the smoke chamber with a microscope.

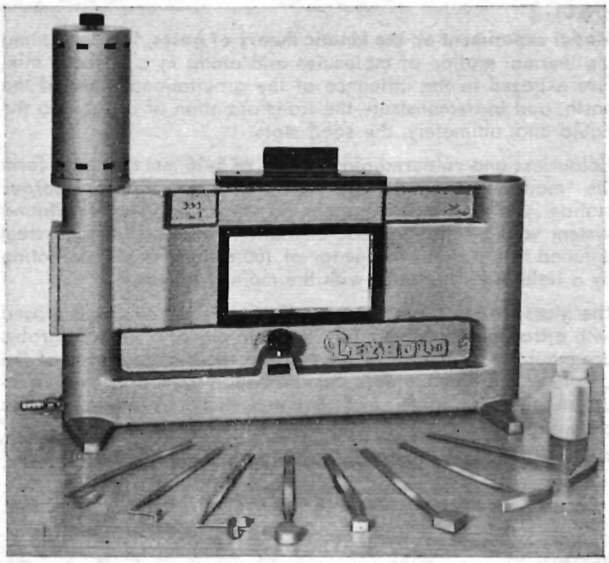


372 51

372 51

Smoke chamber, for observing Brownian motion of smoke particles in dark-field illumination. The chamber, a hollow cube of approx. 25 mm edge length with base, has two lateral illuminating windows and an observation window on top. The smoke is blown into one of the two ends by means of the rubber tube supplied with the instrument.

This requires a microscope with approx. 100-fold magnification, objective max. × 30, e.g. microscope 442 13, and an illuminating device (516 02).



373 02 / 03

373 02

Tunnel for observing flow phenomena in liquids, with motor for connection to the 220 V mains, approx. 30 to 50 cm high, 56 cm wide; for demonstrating the lines of flow around objects of various shapes that are immersed in flowing water. The flow is produced by a turbine with variable-speed electric motor and rendered visible by means of suspended particles; it can be observed through a window. The apparatus is very suitable for demonstrating flow phenomena in projection. An optical bench which carries the necessary optical parts can easily be inserted.

The set of 8 sections comprises: square lamina, rectangular lamina, open semicylinder, cylinder, square section, streamlined section, nose piece of a streamlined section, aerofoil.

Complete with variable motor for 220 V, 8 sections, and bottle with plastic dust, but without projection device.

Recommended for projection:

1 Small optical bench	460 41/42
4 Leybold bosses	301 01
1 Lamp-house	450 60
1 Lamp, 6 V, 30 W	450 51
1 Lens in frame, dia. 40 mm, f = 200 mm	460 04
2 Lenses in frame, dia. 120 mm, f = 200 mm	460 10
1 Transformer, 6 V, 30 W	562 76

373 03

Tunnel for observing flow phenomena in liquids, with electric motor for **110 V** mains.

374 29

Trough for experiments in hydrodynamics, to observe the flow patterns in a liquid when an object is dragged through its surface strewn with lycopodium powder. The starting vortex and the formation of vortex patterns behind the object are easy to observe. Approx. 93×30 cm² in size, with guide edges for the rollers carrying the sections.

Additionally required: Set of differently shaped sections 374 30.

See also "LEYBOLD Physics Leaflets", DC 532.582; a.

374 30

Set of differently shaped sections for dragging through the trough (374 29).

The set comprises: 2 plane plates, 1 cylinder, 1 semicylinder, 1 streamlined section, 1 nose piece of a streamlined section, 1 aerofoil; with supporting carriage on rollers and shaker for lycopodium powder.

413 08

Lycopodium powder, 10 g.

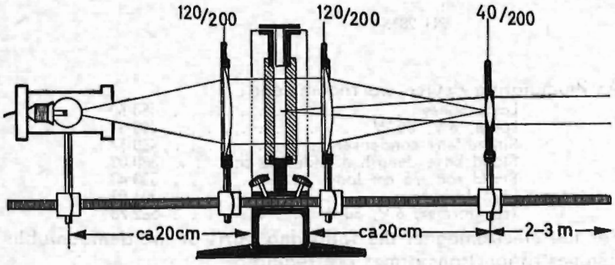
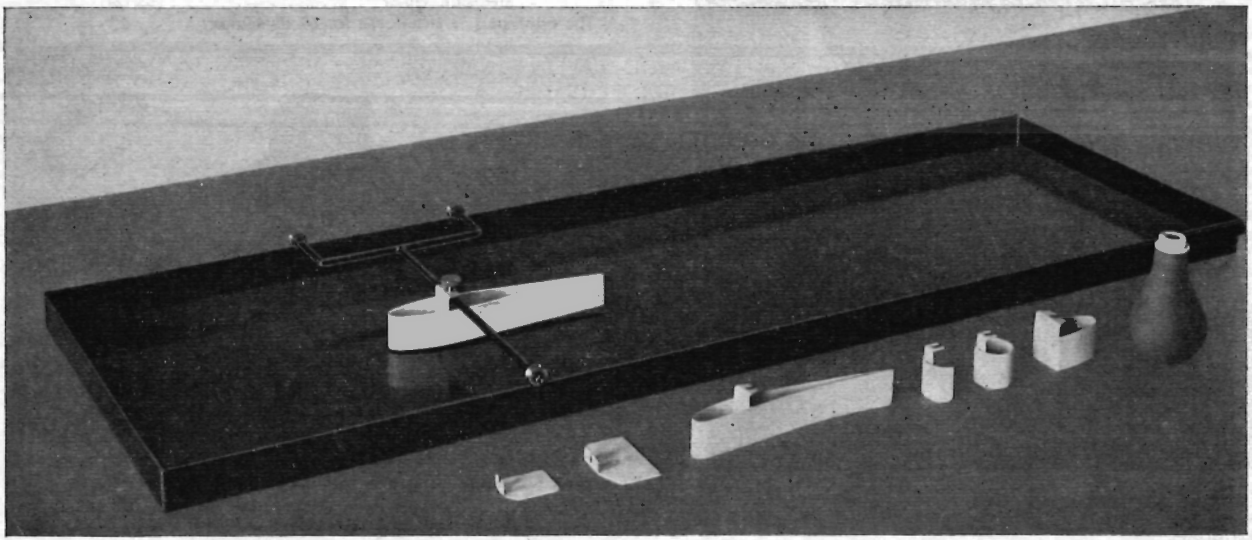
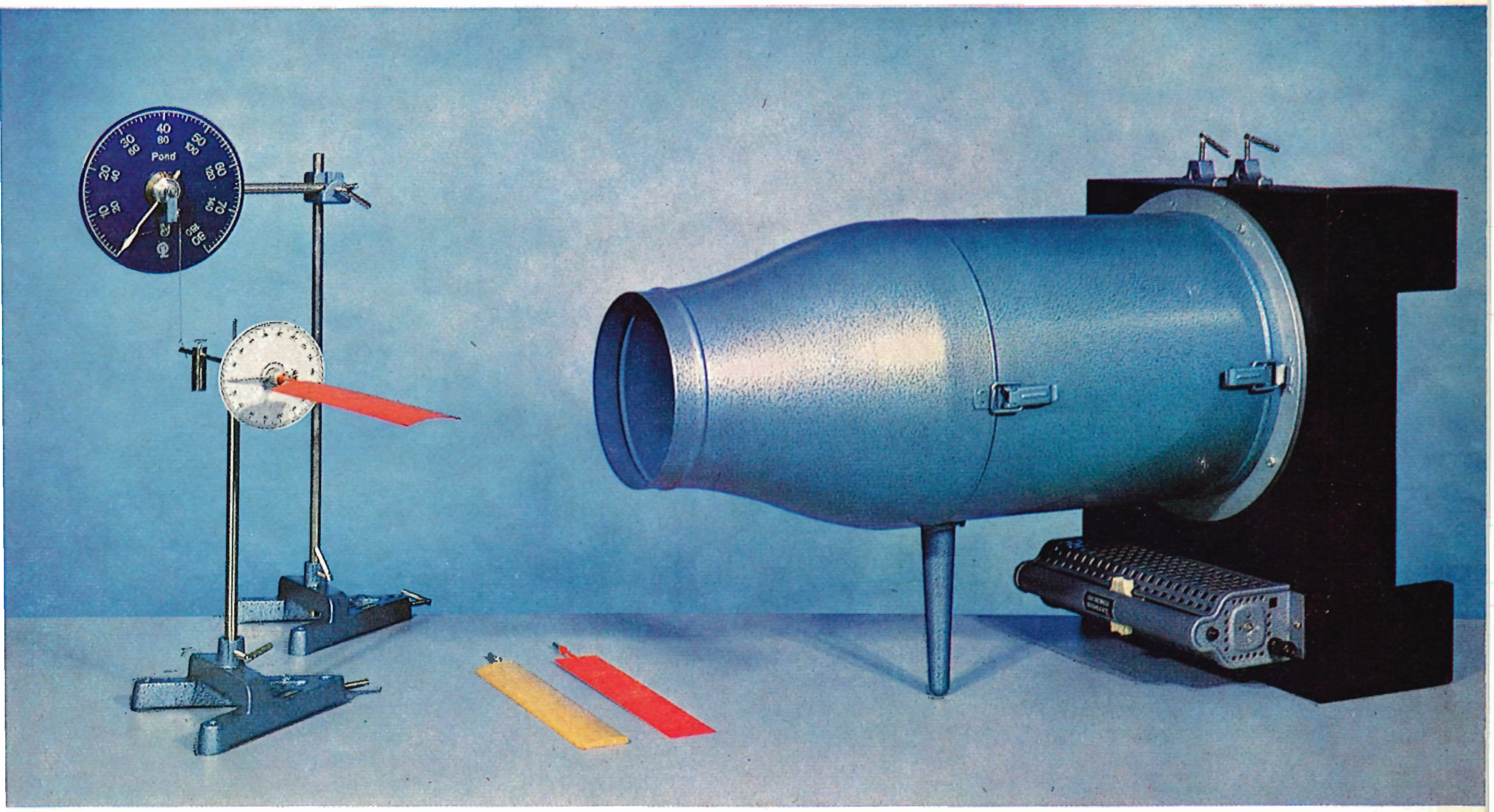


Fig. 20
Schematic representation of the arrangement of the projection device for the tunnel.

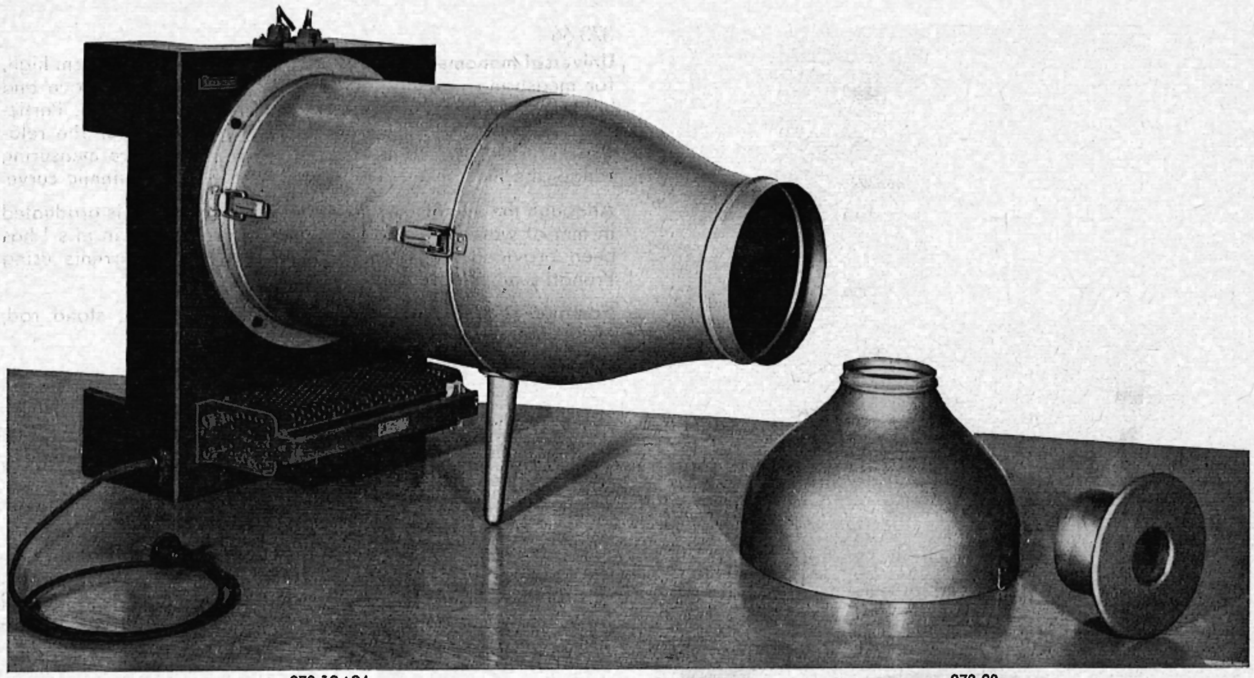


374 29 / 30



Lift and drag on aerofoils
in the blast of the blower
are measured with
the two-component balance.

PLATE I

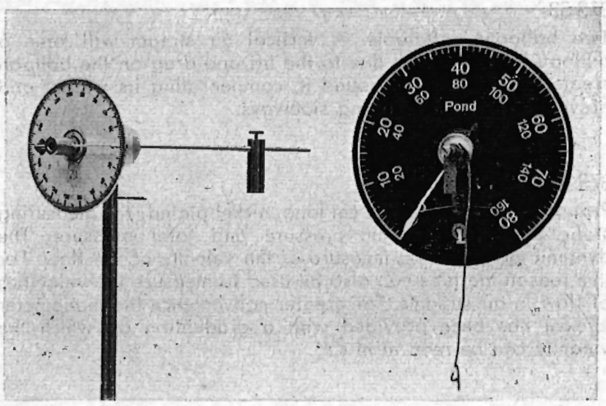


373 19 / 24

373 20

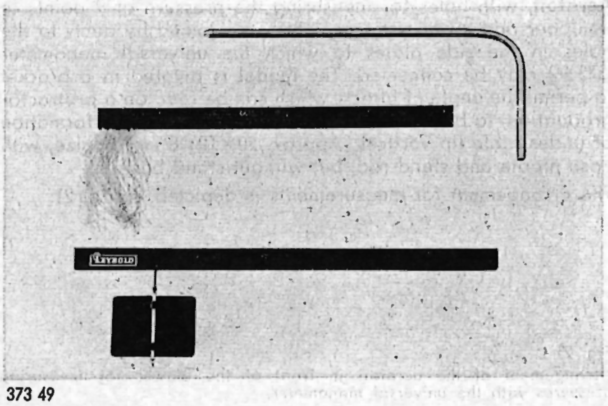
373 19

Blower with electric motor, for connection to the 220 V mains; for experiments in air streams. A fundamental piece of apparatus enabling a great variety of experiments to be done when combined with the many ancillary parts described in the next few pages. With these means the fundamental laws of aerodynamics may be derived experimentally, and measurements on various models can help to create the basis for an understanding of modern flying.



373 30

373 32



373 49

The apparatus produces a homogeneous air stream of variable speed. The air is sucked in by a fan, distributed by means of baffles and expelled as a homogeneous stream of 8 m s^{-1} maximum speed from an outlet opening of 300 mm diameter. If a nozzle of 180 mm diameter is fitted on this, speeds of up to 13 m s^{-1} can be obtained. With the nozzles listed below (373 20) wind speeds of up to 22 m s^{-1} can be attained.

The apparatus is mounted on a base board, approx. 40×50 cm^2, and may be used horizontally or vertically; complete with driving motor for 220 V, 85 W, rheostat, switch and cable, as well as one detachable nozzle of 180 mm diameter.

373 24

Blower with electric motor, for connection to 110 V mains, in all other respects like 373 19.

373 20

Set of nozzles for the blower. The set comprises one nozzle of 100 mm diameter for wind speeds up to approx. 19 m s^{-1} and one nozzle of 50 mm diameter for wind speeds up to approx. 22 m s^{-1}.

The nozzles are fitted onto the blower opening and secured with a bayonet catch. The air blown through them will remain free from turbulence.

373 30

Two-component balance, for measuring drag and lift on aerofoils as a function of their shape and the angle of attack. With scale for adjusting angle of attack, clamping device for holding the aerofoils, and counterweight, as well as one stand rod with vertical and horizontal bearing pins.

Additionally recommended for setting up:

1 Stand base, length of sides 20 cm	300 02
1 Torsion spring balance	373 32

373 32

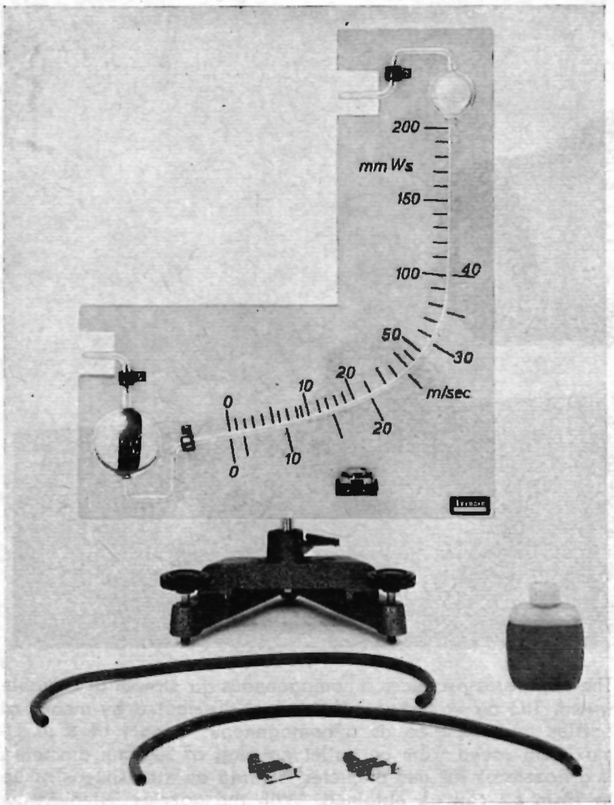
Torsion spring balance, scale diameter approx. 175 mm, with clearly visible graduation; 2 ranges, viz. 80 and 160 p (g wt). Particularly suitable for measurements with the two-component balance (373 30).

Additionally recommended for setting up:

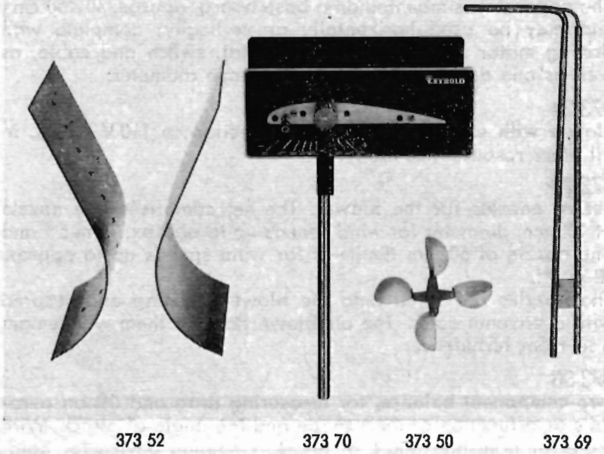
1 Stand base, length of sides 20 cm	300 02
1 Stand rod, 25 cm long	300 41
1 Stand rod, 50 cm long	300 42
1 Leybold boss	301 01

373 49

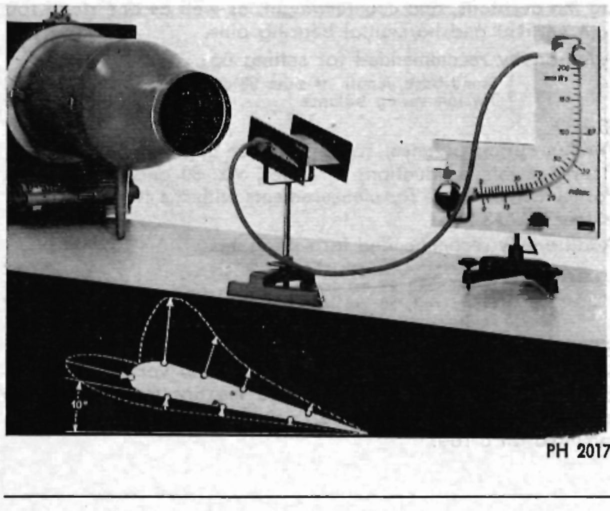
Set of probes, to explore states of flow and vortices; consists of a flame probe for connection to the gas mains, a thread comb and a rotatable plate, approx. 70×50 mm^2 in size, mounted on a rod.



373 66



373 52 373 70 373 50 373 69



PH 2017

Fig. 21
Arrangement of the aerofoil in front of the blower for measuring pressures with the universal manometer.

373 66

Universal manometer, with scale board, 35 cm wide, 42 cm high, for measuring pressures of 0 to 200 mm of water above and below atmospheric pressure, and pressure differences. Particularly suitable for all measurements in air currents. The relative accuracy of reading is constant over the entire measuring range, the manometer tube being bent in a logarithmic curve.

Although the manometer has a petroleum filling, it is graduated in mm of water column (Ws). Another graduation in m s^{-1} has been provided for reading the speeds of air currents using Prandtl's tube.

Complete with stand base with levelling screws, stand rod, level, rubber tubes and petroleum filling.

391 15

Manometer fluid, coloured; for re-filling universal manometer, bottle holding 100 cm^3.

373 50

Cup anemometer, simple demonstration model; dia. approx. 11.5 cm, with four hemispheres, without base. To be mounted on a bearing pin, e.g. the stand of the two-component balance (373 30).

373 52

Pair of curved sheet-metal guides, approx. 26×15 cm^2, for measuring the variations in pressure within an adjustable model nozzle. One of the guides is provided with holes which can be connected to the universal manometer for measurement.

The parts can be arranged in front of the blower by means of stand rods and bosses.

373 53

Two balloons, inflatable. A vertical air stream will keep a balloon hovering in it, due to the lift and drag on the balloon created by the airflow round it, compensating its weight and preventing it from escaping sideways.

373 69

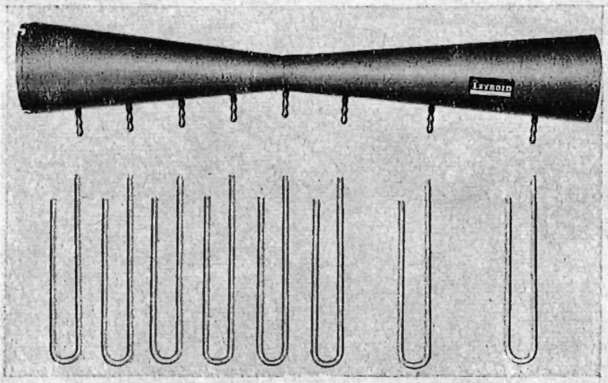
Prandtl's tube, approx. 35 cm long, nickel-plated; for measuring static pressure, dynamic pressure and total pressure. The dynamic pressure is a measure of the velocity of the flow. For this reason the tube can also be used to measure the velocities of flow in air streams. For greater convenience the manometer (373 66) has been provided with a graduation on which the velocity can be read in m s^{-1}.

373 70

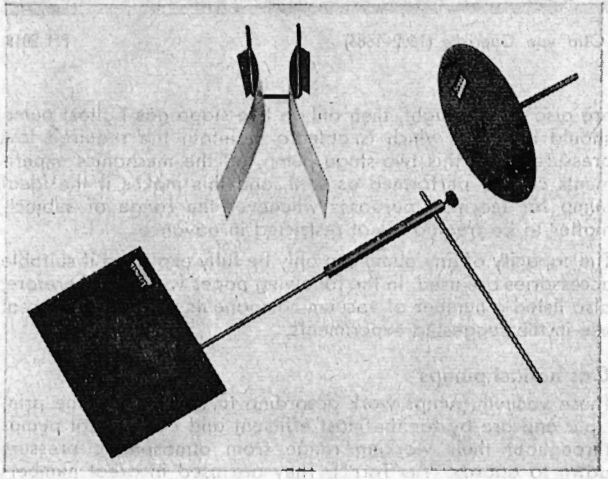
Aerofoil, with holes for measuring the pressure at 9 points in its upper and lower surfaces, which are joined by ducts to the holes in the side plates to which the universal manometer (373 66) may be connected. The model is pivoted in a bracket to permit the angle of attack, which can be read on a protractor graduation, to be varied. The side plates prevent the formation of undesirable tip vortices. Approx. 20×10×8 cm^3 in size, with hose nipple and stand rod, but without stand base.

The arrangement for measurements is depicted in Fig. 21.

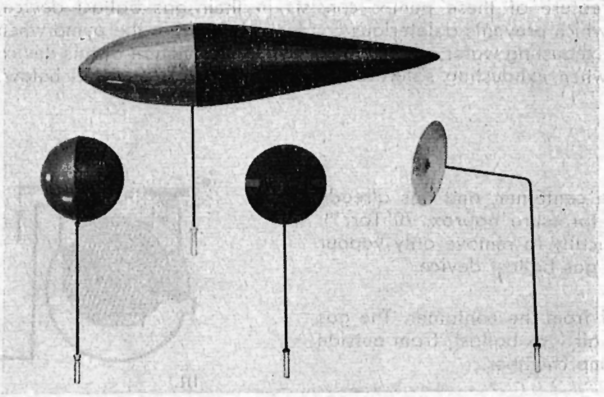
373 71



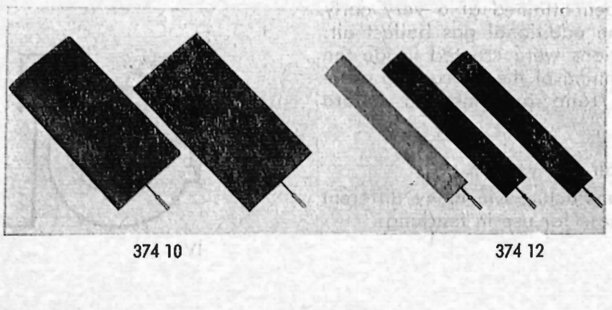
373 72



373 76 374 18 373 74



374 09



374 10 374 12

373 71

Venturi tube, approx. 65 cm long, with 8 measuring points; for measuring the pressure distribution in a tube with a constriction. The air stream is produced by the blower fitted with the 100 mm nozzle (373 20). The venturi tube can be directly fitted to this arrangement.

For measurements we recommend:

Set of 8 U-tubes	373 72
or	
Universal manometer	373 66

373 72

Set of 8 U-tubes, for simultaneous determination of pressure at all measuring points of the venturi tube (373 71). For the experiments the U-tubes must be filled with coloured water. Approx. 23 cm long; with hose nipples.

373 74

Plate for demonstrating the aerodynamic paradox. Dia. approx. 150 mm, with spacing pins and holes for measuring the pressure distribution. Will adhere to the nozzle opening of the 100 mm nozzle (373 20) if exposed to the full impact of the blast there.

373 76

Rotatable plate, simplified model of an aircraft wing, to study the couples resulting from lift and drag that act on an aerofoil.

Plate, approx. 16×12 cm² in size, rotatable about an axle that is capable of parallel displacement along one side. When exposed to the blast, the plate will adjust itself to a certain angle of attack; with counterweight and clamping device, but without stand.

374 09

Set of test objects to study form drag. All objects have a maximum diameter of 83 mm, so that their form drags are directly comparable, and are provided with mounting stems.
The set comprises:

1 Streamlined object with detachable pointed tail
1 Sphere with detachable hemisphere
1 Plate, circular (with two clips for demonstrating vortices)
1 Plate, circular, on screw shaft (can be exchanged for self-made objects).

Recommended for use with the blower, the two-component balance (373 30), and the torsion spring balance (373 32).

374 18

Set of 2 curved metal sheets that will approach each other if an air stream is made to pass between them; approx. 15×9 cm² in size, with U-shaped holder. The metal sheets can also be blown by mouth.

374 10

Set of large aerofoils, for determining lift and drag at low velocities, and to demonstrate tip vortices, comprising one flat plate and one plate having an aerofoil cross-section, both 28×14 cm² in size, with holding shaft.

Recommended for use with the blower, the two-component balance (373 30), and the torsion spring balance (373 32).

374 12

Set of aerofoils, for measuring lift and drag as a function of the shape of the cross-section and the angle of attack consisting of a plane plate, a curved plate and a plate having an aerofoil cross-section, all approx. 30×5 cm² in size, with holders for attaching them to the two-component balance.

Recommended for use with the blower, the two-component balance (373 30), and the torsion spring balance (373 32).

Fig. 22 Demonstration of the Magdeburg hemispheres by Otto von Guericke (1602–1686) PH 2018

LEYBOLD is the oldest firm in the world active in the high vacuum field. In 1904 we built the first rotary mercury pump, invented by Professor Gaede. Since then, Leybold has been ceaselessly active in high vacuum research and in the development, construction and manufacture of high vacuum pumps. Many new pumps, such as rotary vane and piston pumps employing the gas ballast principle, steam ejector, diffusion, molecular and getter pumps were developed and constantly improved, and gauges and high-vacuum-tight components were created. To-day we are able to supply suitable equipment for any application of vacuum in research and industry, the high quality and performance of which are universally acknowledged.

We have also devoted much attention to the use of vacuum pumps in teaching. We offer a considerable number of vacuum pumps for this purpose and are pleased to give advice on the choice of the right type, depending upon the subject-matter to be dealt with.

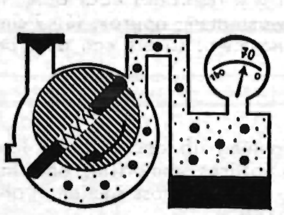
If the subject-matter to be taught is restricted to mechanical processes at reduced pressure, water jet pumps, hand air pumps or single-stage gas ballast pumps are suitable. If, however, the electrical phenomena in rarefied gases, which lead from a study of cathode and X-rays to the problems of modern physics, are also to be taught, then only a two-stage gas ballast pump should be used, which is able to maintain the required low pressure. With this two-stage pump, all the mechanics experiments can be performed as well, and this makes it the ideal pump for teaching purposes whenever the range of subject-matter to be treated is not restricted in advance.

The capacity of any pump can only be fully exploited if suitable accessories are used. In the following pages we have, therefore, also listed a number of vacuum components which are of great use in the suggested experiments.

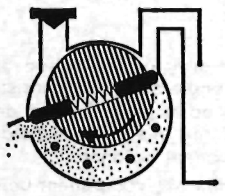
Gas ballast pumps

These vacuum pumps work according to the rotary vane principle and are by far the most efficient and economical pumps throughout their working range from atmospheric pressure down to approx. 1/100 Torr*). They are used in great numbers in research and industry and are, therefore, equal to any demands that may be made on them in teaching. A special feature of these pumps consists in their gas ballast device, which prevents deleterious condensation within the pump when exhausting water or solvent vapours. The function of this device when exhausting saturated water vapour is illustrated below:

Fig. 23 **Gas ballast principle**



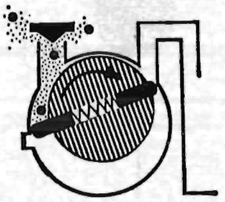
I.



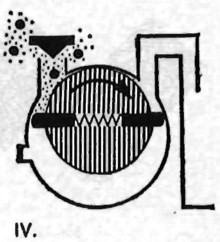
II.

1. **Start of pumping cycle**
   The pump is connected to the container, and has already evacuated almost all the air (pressure approx. 70 Torr*). Therefore the pump has practically to remove only vapour particles. It operates with the gas ballast device.
2. **Start of compression**
   The pump chamber is shut off from the container. The gas ballast valve now opens, and air (gas ballast) from outside flows through it to fill the pump chamber.
3. **Start of exhaust**
   The exhaust valve is forced open, and vapour and gas particles are ejected. The excess pressure required for effecting this ejection has been attained at a very early stage by the admission of the additional gas ballast air. In this manner similar conditions were created inside the pump chamber as in the beginning of the evacuation process: favourable gas/vapour ratio and ejection before condensation can take place.
4. **Exhaust**
   The pump continues to eject air and vapour.

These gas ballast pumps are manufactured in many different sizes. We recommend three of these for use in teaching:



III.



IV.

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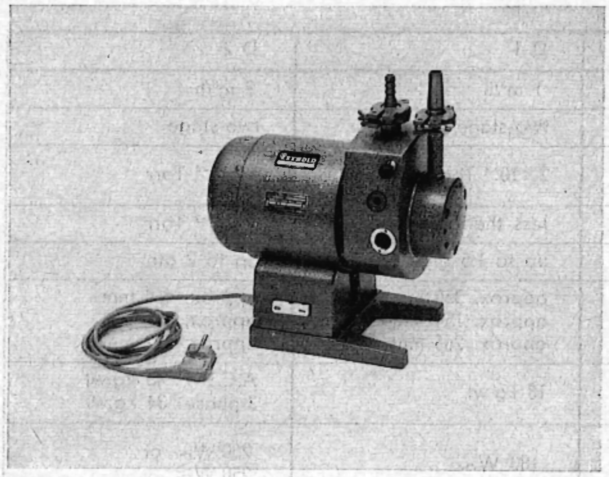
*) 1 Torr = 1 mm Hg.

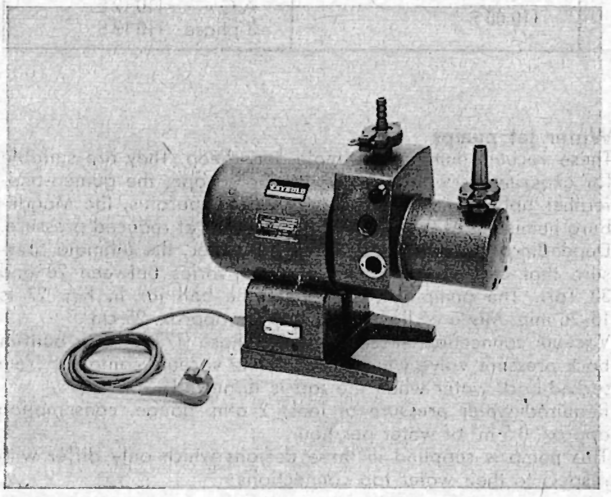


104 10 S

104 10 S

Single-stage gas ballast pump S 1, with A.C. motor for connection to the 220 V, 50 c/s mains; consisting of pump S 1 with motor (104 10), male ground joint NS 19/38 (184 91) and hose nipple (183 11). The pump and motor of this type form a very compact, easy-to-move unit, as pump axle and motor axle are directly coupled. One male ground joint as intake port and a hose nipple which may be used as intake or exhaust port are supplied with the pump. Both are connected by means of the small flanges described on page 47. The electric switch is provided at the base of the motor.

The displacement of these pumps is much greater than that of water jet pumps or hand air pumps (cf. p. 46), and all vacuum experiments in the fields of mechanics and heat can, therefore, be performed fast and reliably with them. On account of its limited ultimate pressure this pump is not suitable for experiments on electric discharges in gases.



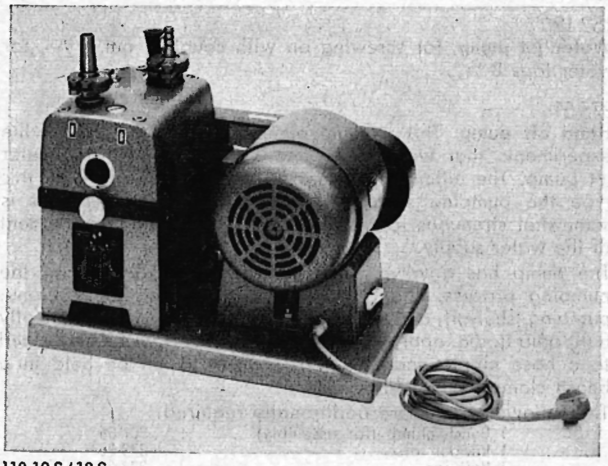
110 00 S

110 00 S

Two-stage gas ballast pump D 1, with A.C. motor for connection to the 220 V, 50 c/s mains, consisting of pump D 1 with motor (110 00), male ground joint NS 19/38 (184 91) and hose nipple (183 11). This pump has all the external characteristics and advantages of the above-described type S 1. However, it has two stages which are connected behind one another, so that a substantially lower ultimate pressure is attained both with and without gas ballast; with the use of the gas ballast device, ice can be produced under a bell jar by the evaporation of water. Without the gas ballast device, discharge tubes of all kinds and cold cathode X-ray tubes can be operated after a suitable pump-down time.

The pump can also be recommended as an easily movable second pump which can be kept free from all impurities and always ready for use for gas discharge experiments with (closed) adaptor (378 00 or 554 00) in position.

The tubes for gas discharge experiments are described on pp. 137–140.



110 12 S / 13 S

110 12 S

Two-stage gas ballast pump D 2, with A.C. motor for connection to the 220 V (or 230–250 V **) in Great Britain), 50 c/s mains, consisting of a pump D 2 (110 10), frame with motor (110 12 L), male ground joint NS 19/38 (184 91) and hose nipple (183 11). This pump is the most efficient type we suggest for use in teaching. It fulfills all requirements: mechanics experiments can be performed without loss of time on account of the large pumping speed, and even small leaks in the experimental arrangement will not be felt. Water can be turned to ice under a bell jar within a relatively short space of time, and in the discharge experiments, too, the large displacement constitutes an additional advantage.

The pump may be used to produce excess pressures up to 1 atm. gauge in intermittent operation.

The pump is mounted on a base plate together with the motor and provided with V-belt drive. A male ground joint as intake port and a hose nipple which may be used as intake or as exhaust port at will are supplied with it; both are provided with the small flanges described on p. 47. For these pumps we recommend permanent installation on a trolley as shown in Fig. 24, p. 47 (598 10).

110 13 S

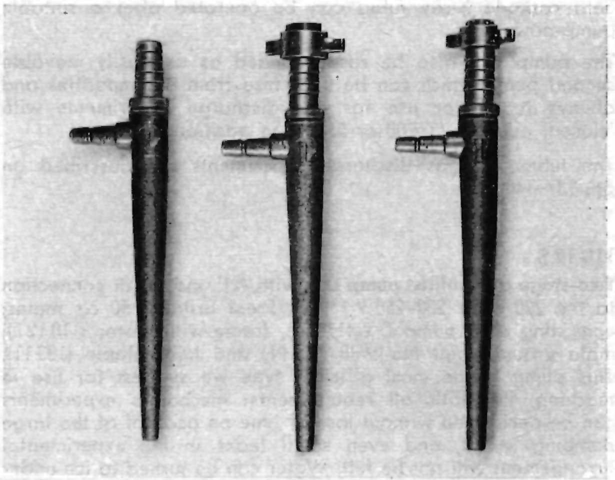
Two-stage gas ballast pump D 2, with three-phase motor for connection to 220/380 V (or 400–440 V **) in Great Britain), 50 c/s; consists of pump D 2 (110 10), frame with motor (110 13 L), male ground joint NS 19/38 (184 91) and hose nipple (183 11).

**) Please state mains voltage when ordering.

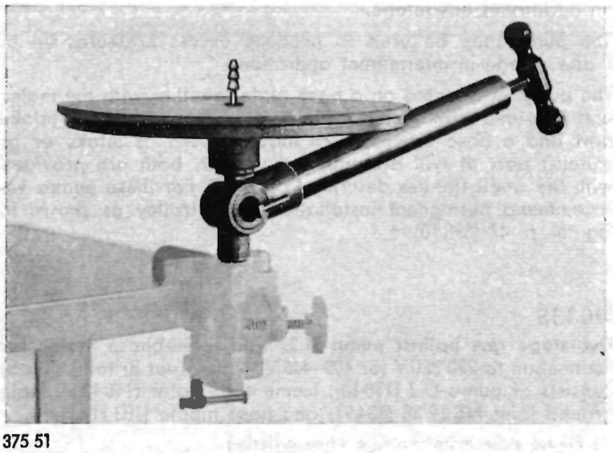
Gas ballast pumps

Type	S 1	D 1	D 2
Displacement	1 m³/h	1 m³/h	2 m³/h
Design	single-stage	two-stage	two-stage
Ultimate pressure of permanent gases without gas ballast	6×10^{-2} Torr	2×10^{-4} Torr	2×10^{-4} Torr
Ultimate total pressure with gas ballast	less than 5 Torr	less than 6×10^{-2} Torr	1×10^{-2} Torr
Compression (absolute pressure)	up to 1.5 ata	up to 1.5 ata	up to 2 ata
Dimensions: Length Width Height *)	approx. 288 mm approx. 154 mm approx. 265 mm	approx. 350 mm approx. 154 mm approx. 265 mm	approx. 460 mm approx. 315 mm approx. 292 mm
Weight	17 kg wt	18 kg wt	A.C.: 43 kg wt 3-phase: 34 kg wt
Motor **) with cable, plug and switch; output	180 W~	180 W~	250 W~ or 250 W≊
Oil filling: (Supplied complete with first filling; for re-fills use oil N 41 [177 01])	200 to 350 cm³	200 to 350 cm³	220 to 850 cm³
Cat. No.	104 10 S	110 00 S	A.C.: 110 12 S 3-phase: 110 13 S

*) Without male ground joint
**) Please state available mains voltage



152 10 152 11 152 12



375 51

Water jet pumps

These vacuum pumps are simple and cheap. They are suitable for experiments with the bell, the baroscope, the guinea-and-feather apparatus, the pressure of air apparatus, the Magdeburg hemispheres, and to make water boil at reduced pressure. Depending upon the pressure of the water, the ultimate pressure that can be attained with them varies between 20 and 30 Torr. The pump-down time for the bell jar in Fig. 27 is 15–20 min. Made of light metal, length approx. 25 cm.
Vacuum connection: Hose nipple for hose (172 02) with built-in back pressure valve which protects the vacuum container from sucked-back water when the tap is turned off.
Required water pressure at least 2 atm. gauge, consumption approx. 0.5 m³ of water per hour.
This pump is supplied in three designs which only differ with respect to their water tap connections:

152 10
Water jet pump, with hose nipple, external dia. 17 mm.

152 11
Water jet pump, for screwing on with coupling nut R ³/₄", for water taps B ¹/₂".

152 12
Water jet pump, for screwing on with coupling nut R ¹/₂", for water taps B ³/₈".

375 51
Hand air pump. This vacuum pump can be used for all the experiments that were mentioned in the case of the water jet pump. The ultimate pressure is approx. 50 Torr. With this type the pumping speed is limited and the experiment is somewhat strenuous to perform; however, one is independent of the water supply.
The pump has a valve which acts automatically during the pumping process, and a three-way cock with the positions: pumping, shut-off, and admit air. The base plate is permanently built onto it, dia. approx. 25 cm. Rubber tubes can be connected to a hose nipple and the entire assembly can be held in a bench clamp by the stand rod.
The following parts are additionally required:

1 Bench clamp (for assembly)	301 06
1 Rubber disc	378 36
1 Bell jar	378 56

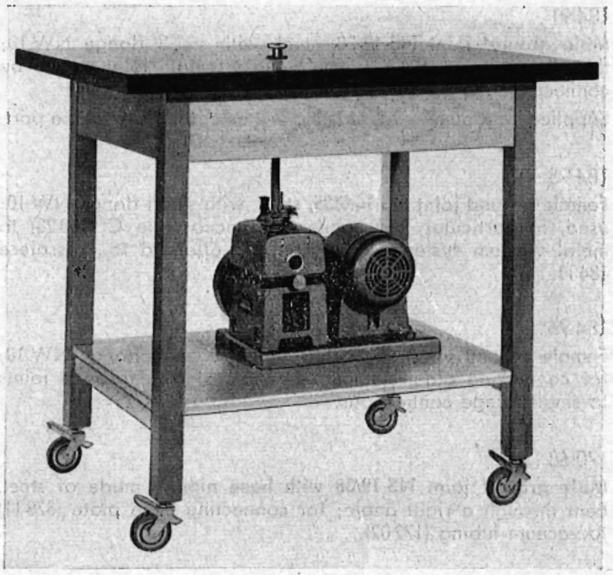
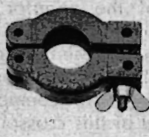


Fig. 24 PH 2019
Trolley (598 10) with permanently mounted gas ballast pump D 2 (110 12 S) and lengthened intake port (379 20) in an easily transported arrangement that is always ready for use.
The pump is mounted on the shelf below the table, leaving the entire table free for the experimental assembly. Particularly suitable for experiments with the vacuum bell jar, discharge tubes, and the X-ray tube (554 27) in X-ray shield (555 93).

183 11

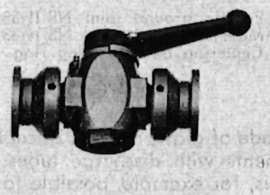
183 21



183 41

184 41

184 11



174 91

173 24

Accessories for vacuum pumps

598 10
Trolley, for permanent installation of gas ballast pump D 2. Beech frame, 90 cm high, table covered with black formica, 75×100 cm², with one hole for introducing the lengthened intake port (379 20) when connecting a vacuum system, and one shelf. On rubber-tyred wheels, each wheel separately lockable.

379 20
Lengthened intake port, for installing a pump D 2 on the shelf of the trolley (598 10); approx. 39 cm long, both ends provided with small flange NW 10 and a centering and clamping ring (183 21/41).

Parts with small flanges

For many years now connections consisting of metal flanges with rubber seals have been found highly serviceable in vacuum technology. Such connections are easy to strip and reassemble in another arrangement according to the required purpose. Transition pieces for glass apparatus and rubber tubes are provided. For the first time we also recommend these parts for use in teaching. Since they are unbreakable, put together without grease and since, moreover, these connections are made by tightening one single winged nut, they are very convenient to use. The parts listed here are only a small selection from our very extensive range. On request we shall be pleased to send you additional information.

183 11
Hose nipple with small flange NW 10*), made of light metal, for vacuum tubing (172 02). One of these is supplied with each of the pumps S 1, D 1 and D 2 and may be used as intake or exhaust port as desired.

183 21/183 41
Centering and clamping ring. This component will hold small flange connections NW 10 together, vacuum-tight. It consists of a metal ring with a perbunan ring stretched upon it, and a clamping ring with a winged nut. The ring is placed between the two flanges to be connected, the clamping ring is laid around them from the outside, and the nut tightened to press them together. The seal becomes vacuum-tight by simply tightening the nut. 2 centering and clamping rings are supplied with each of the pumps S 1, D 1 and D 2.

184 11
Crosspiece with 4 small flanges NW 10, of light alloy; for assembling vacuum arrangements with air inlet valve and gauge. For example see p. 48.

184 41
Blind flange NW 10, of light alloy; for closing one of the flanges of the crosspiece, for example if no gauge is to be provided.

174 91
Vacuum ball valve, brass, with small flanges NW 10; for blocking metal vacuum lines. The operating lever is covered with red plastic, easy to see from a distance, and is turned through 90° to close the valve; its position indicates to the onlookers whether the valve is open or closed.

173 24
Air inlet valve, steel, with small flange NW 10; operated by wing nut and connected to crosspiece (184 11). In experiments with gas discharge tubes an air inlet valve should always be provided, as discharge tubes are difficult to take off the pump without previously admitting air and may easily be damaged if this is tried.

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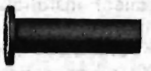
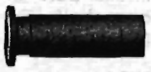
*) NW 10 means nominal width 10 mm

184 91



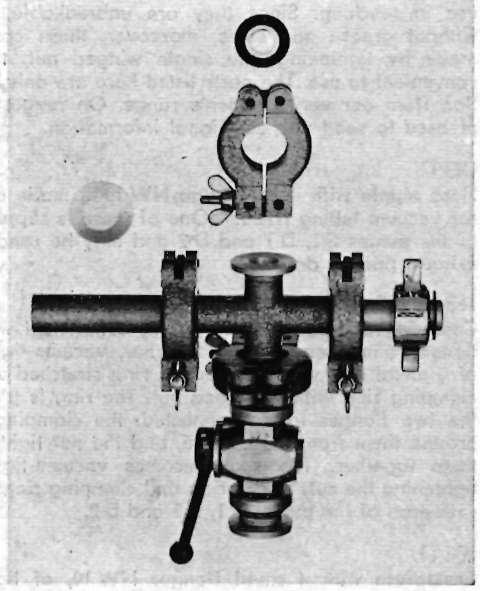
184 95



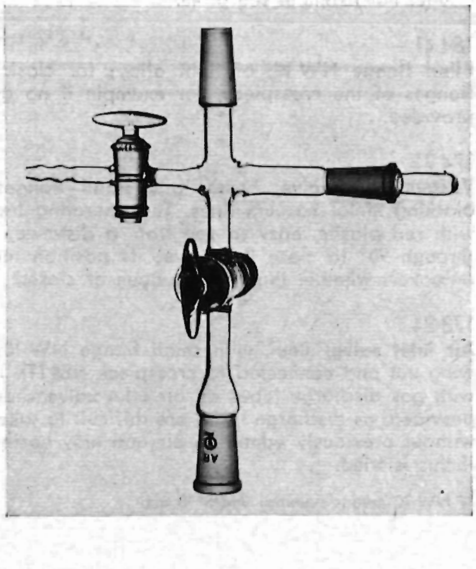
184 96

170 68

170 69



378 00



554 00

184 91

Male ground joint NS 19/38, steel, with small flange NW 10; this should be used whenever a glass female joint has to be connected to a metal vacuum line.

Supplied with pumps S 1, D 1 and D 2 as detachable intake port.

184 95

Female ground joint NS 14.5/35, steel, with small flange NW 10; used, in particular, for connecting vacuoscope C (160 23) to metal vacuum systems, and generally attached to crosspiece 184 11.

184 96

Female ground joint NS 19/38, steel, with small flange NW 10; for connecting older pumps with integral male ground joints to small flange connections.

170 68

Male ground joint NS 19/38 with hose nipple, made of steel, bent through a right angle; for connecting base plate (378 11) to vacuum tubing (172 02).

170 69

Female ground joint NS 19/38 with hose nipple, steel, bent through a right angle; for connecting vacuum tubing (172 02) to older gas ballast pumps with integral male ground joints.

378 00

Adaptor, made of metal, especially suitable for experiments with discharge tubes. This accessory is composed of components with small flanges and can be mounted directly on the small flange of the pump (S 1, D 1 or D 2). For this the male ground joint NS 19/38, belonging to the pump, should be taken off and mounted on top of the adaptor. The adaptor comprises a straight-through valve to shut off the pump, and an air-inlet valve. With the help of these two components it is, for example, possible to adjust the pressure inside the discharge tube while the pump is running. All components are connected to a crosspiece. One end of this crosspiece is available for connecting a vacuum gauge and is normally closed with a blind flange. The unit comprises the following parts, which can also be ordered separately:

1 Crosspiece	184 11
1 Vacuum ball valve with small flange	174 91
1 Air inlet valve with small flange	173 24
1 Blind flange NW 10	184 41
1 Female ground joint NS 14.5/35	184 95
4 Centering and clamping rings	183 21/41

The male ground joint NS 19/38, which is also required, is supplied with pumps S 1, D 1 and D 2.

In the case of older pumps a small flange is permanently mounted on the pump, without intervening small flange connection. For these the following parts are additionally required:

1 Female ground joint NS 19/38 with small flange	184 96
1 Male ground joint NS 19/38 with small flange	184 91
1 Centering and clamping ring	183 21/41

554 00

Adaptor, made of glass, approx. 24 cm high; especially suitable for experiments with discharge tubes. With the help of this adaptor, it is, for example, possible to adjust the vacuum in a discharge tube (554 16), to any desired value while the pump is running and measure it with vacuoscope C (160 23). The unit is provided with a female ground joint NS 19/38 on the pump side and a male ground joint NS 19/38 on the discharge tube side. A stopcock to shut off the pump is provided between these. Laterally, a hose nipple with stopcock for admitting air and gas, and a female ground joint NS 14.5/35 for connecting vacuoscope C are provided. The connections should be greased with high vacuum grease (176 40).

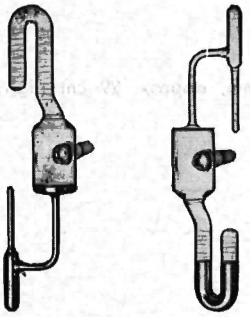
172 02
Vacuum tubing, rubber, int. dia. 7 mm, ext. dia. 17 mm; sold by the metre.

412 73
Pressure tubing, of oil-resistant plastic, is not attacked even after prolonged use by the fine oil spray that always occurs when generating compressed air; approx. 2 m long, int. dia. 8 mm, ext. dia. 15 mm; with two clips.

176 40
Leybold high-vacuum grease P, with low vapour pressure. Used to seal ground joint connections and valves, suitable for the experiments on gas discharge.

177 32
Ramsay grease, thick, for sealing ground joints, to be used in all experiments except gas discharge.

177 42
Ramsay grease, thin, for sealing valves, to be used in all experiments except gas discharge.



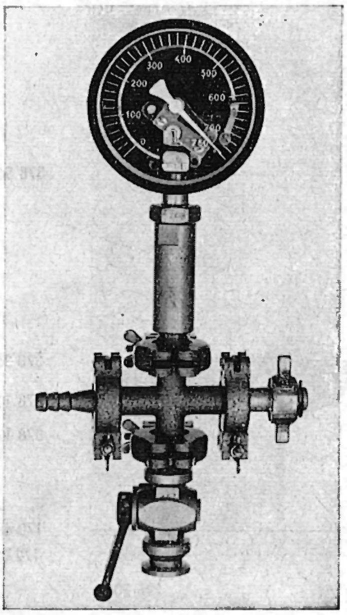
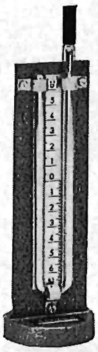


Fig. 25 **Measuring arrangement for the Bourdon gauge.**
The decrease of pressure can be observed with the Bourdon gauge while evacuating. Suitable, for example, for experiments with the glass bell jar in Fig. 26, or with the Magdeburg hemispheres.

Apparatus required:

1 Crosspiece	184 11
1 Vacuum ball valve with small flange	174 91
1 Air inlet valve with small flange	173 24
1 Hose nipple with small flange	183 11 *)
1 Male ground joint NS 19/38 with small flange	184 91 *)
1 Bourdon gauge	379 15
4 Centering and clamping rings	183 21/41

*) Supplied with pumps S 1, D 1 and D 2.



379 05

379 04

177 50
Pizein, for high-vacuum-tight, ground or non-ground joints. Drop point 90° C, working temperature not to exceed 50° C, vapour pressure 10^{-4} Torr; supplied in rods of approx. 70 g.

177 54
White sealing wax, for vacuum-tight sealing, drop point 108° C, working temperature not to exceed 50° C; vapour pressure 10^{-3} Torr; in rods of approx. 100 g.

177 01
Special oil N 41, for pumps S 1, D 1 and D 2, with low vapour pressure; 1 kg in can.

177 21
Mercury, chemically pure, for measuring instruments: 1 kg.

177 23
Mercury, chemically pure, for measuring instruments: 150 g.

Mercury, 99.99 B.P., 50 g in drop bottle (in Great Britain only).

Vacuum gauges

160 23
Vacuoscope C, with male ground joint NS 14.5/35, made of glass, approx. 23 cm long (without mercury).
The apparatus is particularly suitable for observing the pressure when studying gas discharges in the discharge tube (554 16) and other open tubes.
The vacuoscope has 2 measuring ranges: from 35 to approx. 2 Torr, the U-tube (position II) should be used for measurement, and is provided with an engraved millimetre scale.
For measurements between 3 and 0.05 Torr, the gauge should be turned about the male ground joint as an axis to bring it into position I. It will then work as a compression manometer on the McLeod principle. The arm of the compression part directed upwards is likewise provided with an engraved scale on which pressures may be read in the lower pressure region.

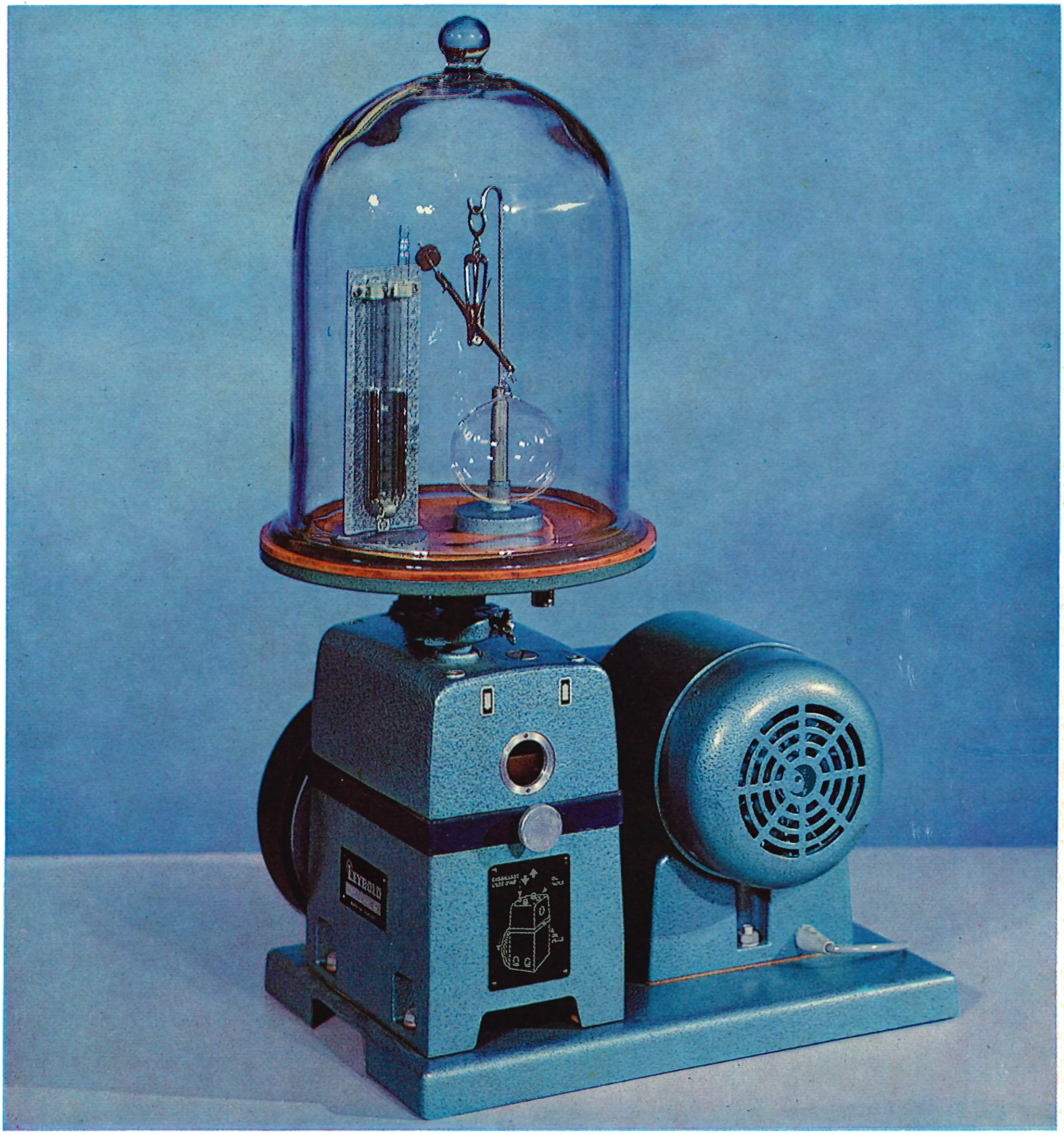
We recommend the following parts for making the connections:

1 Adaptor, made of glass	554 00
or	
1 Adaptor, made of metal	378 00

379 04
U-tube manometer, range: 1,500 to 1 Torr; approx. 90 cm high, on stand with coloured scale clearly visible from a distance. The apparatus indicates the pressure difference from atmospheric pressure; therefore, the values read must be referred to the barometer reading. Easy to fill and protected against sucking back of mercury on the vacuum side. For connection, a hose nipple is provided.
Complete with stand, but without mercury; approx. 1 kg of mercury is required for filling.

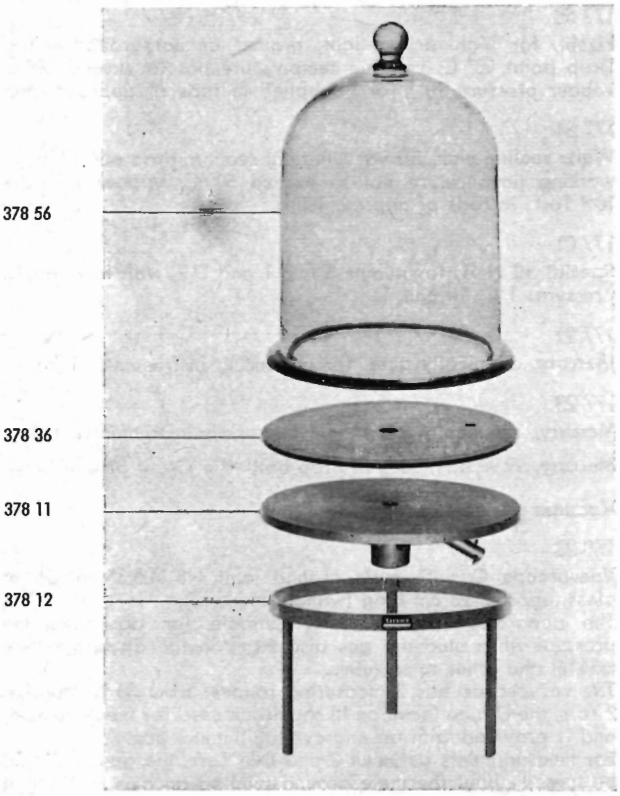
379 05
Short manometer, range: 120 to 2 Torr; U-tube, made of glass, sealed on one side; on metal base with scale 120 mm long. Particularly suitable for measurements under a bell jar. Complete with mercury filling.

379 15
Bourdon gauge, range: 760 to 1 Torr, dial diameter approx. 100 mm.
The gauge contains a Bourdon tube as sensitive element. It has an all-glass front plate so that the working of the measuring system can be observed from the outside. The reading depends upon the atmospheric pressure and must be corrected according to the barometric pressure for exact determinations. The gauge is provided with a female ground joint NS 19/38 for connection. When assembling a measuring arrangement we recommend using the parts shown in Fig. 25.



The glass sphere of the baroscope
experiences a buoyant force in air
which decreases as the pressure
under the bell jar drops.
The ball sinks down.

PLATE II



378 11

Base plate, dia. 260 mm, steel, with air inlet valve. For use with the glass bell jar (378 56) with rubber disc (378 36) interposed. At its centre, the plate is provided with a hole with a female ground joint NS 19/38 fitting the intake port of gas ballast pump D 2, or the male ground joint with hose nipple (170 68).

378 12

Tripod, steel, for holding the base plate when connections are made by means of male ground joint with hose nipple (170 68) and vacuum tubing.

378 36

Rubber disc, dia. 250 mm; for sealing the bell jar placed on the base plate. Much more convenient to use than greased connections.

378 56

Glass bell jar, int. dia. 200 mm, approx. 29 cm high; with ground rim, and carrier knob.

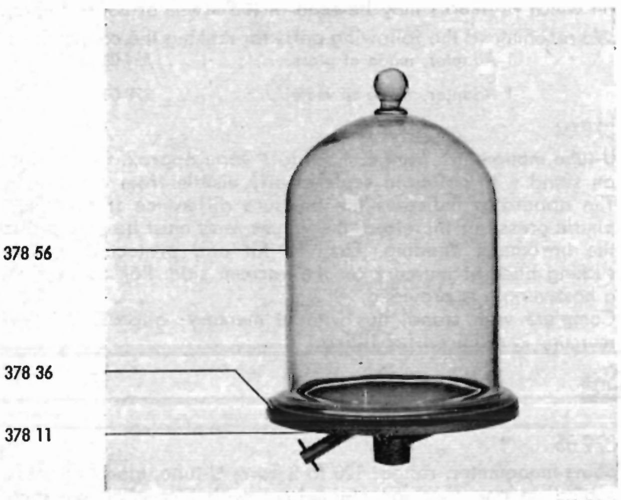


Fig. 26 PH 2021

Fig. 26

Glass bell jar, to be fitted on gas ballast pump D 2. Forms a compact, clear unit with the gas ballast pump. Mounting on the trolley (598 10) has been found most suitable. The pump should then be placed on the intermediate shelf of the trolley and the bell jar should be fitted with the male ground joint from the pump and so mounted on the small flange of the lengthened intake port (379 20) (cf. Fig. 24).

The bell jar consists of the following parts:

1 Base plate, metal	378 11
1 Rubber disc	378 36
1 Glass bell jar	378 56

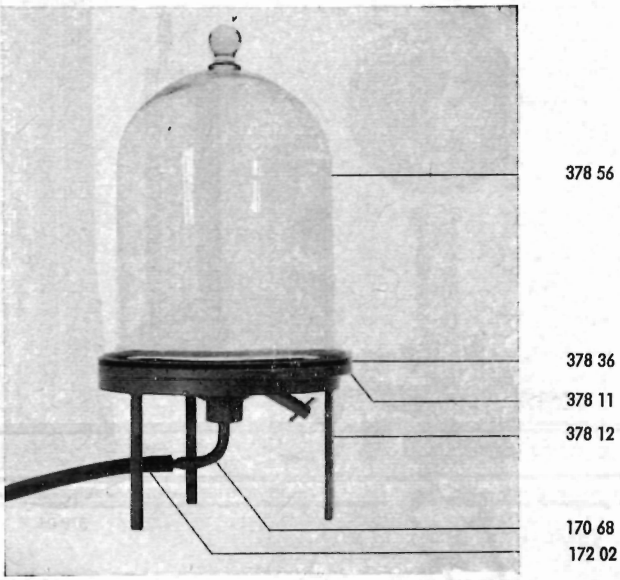


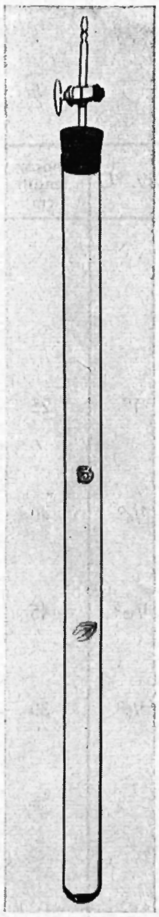
Fig. 27 PH 2022

Fig. 27

Glass bell jar on tripod, evacuated through vacuum tubing by means of a water jet pump or one of the gas ballast pumps S 1, D 1 or D 2. The vacuum tubing is connected using a male ground joint, bent through a right angle, with hose nipple.

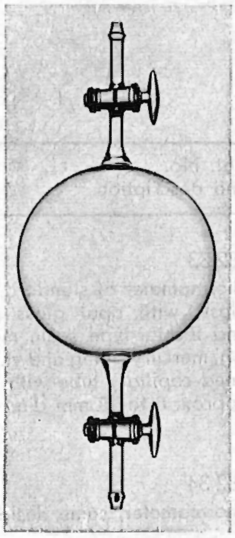
Consists of:

1 Base plate	378 11
1 Rubber disc	378 36
1 Glass bell jar	378 56
1 Tripod	378 12
1 Male ground joint with hose nipple	170 68
1 Length of vacuum tubing	172 02

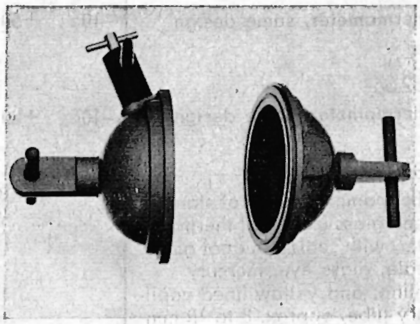


379 00

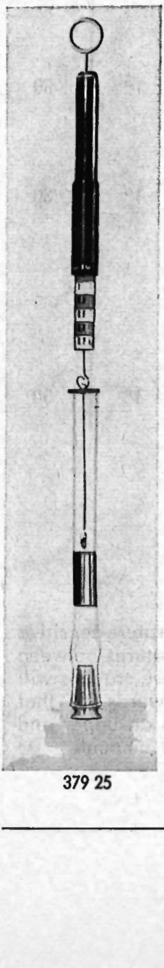
379 08



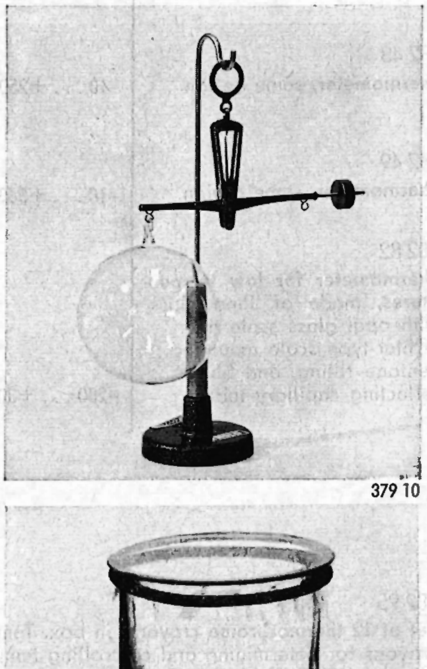
379 07



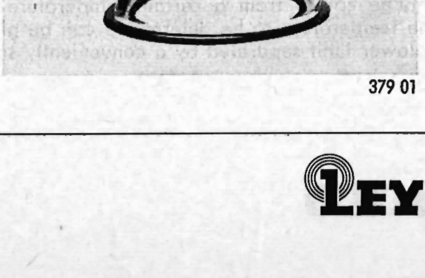
379 09



379 25



379 10



379 01

379 08

Electric bell, for use under the bell jar to show that sound is not propagated in highly rarefied air.

With long supply leads and flat current lead-in plates that can be led through vacuum-tight between rubber disc and bell jar, and sockets mounted on small plate for connection to 4 to 6 V; without transformer or bell jar.

379 10

Baroscope, for use under bell jar (378 56). Weighing beam approx. 13 cm long, with one glass sphere and one displaceable metal weight. At normal atmospheric pressure, these two will be in equilibrium. In vacuo, the sphere will sink down as the buoyant force of the air ceases to act. Complete with glass sphere and stand.

379 00

Guinea-and-feather apparatus, made of glass, approx. 70 cm long, one side closed; with rubber stopper, glass tube with stopcock and hose nipple, and tinfoil ball and feather. The tube should be evacuated with one of the vacuum pumps listed earlier. The tube is easy to clean after removing the stopper.

379 01

Pressure of air apparatus, for demonstrating atmospheric pressure. The air below the membrane is pumped out until the membrane bursts with a loud report. Consists of a glass cylinder, dia. 90 mm, with two beaded, ground rims, a rubber ring and a stock of cellophane membranes. To be placed on the base plate (378 11) interposing the rubber disc (378 36).

379 07

Sphere with two stopcocks, made of glass, for determining the specific gravity of air, dia. approx. 120 mm, with glass stopcocks and hose nipples.

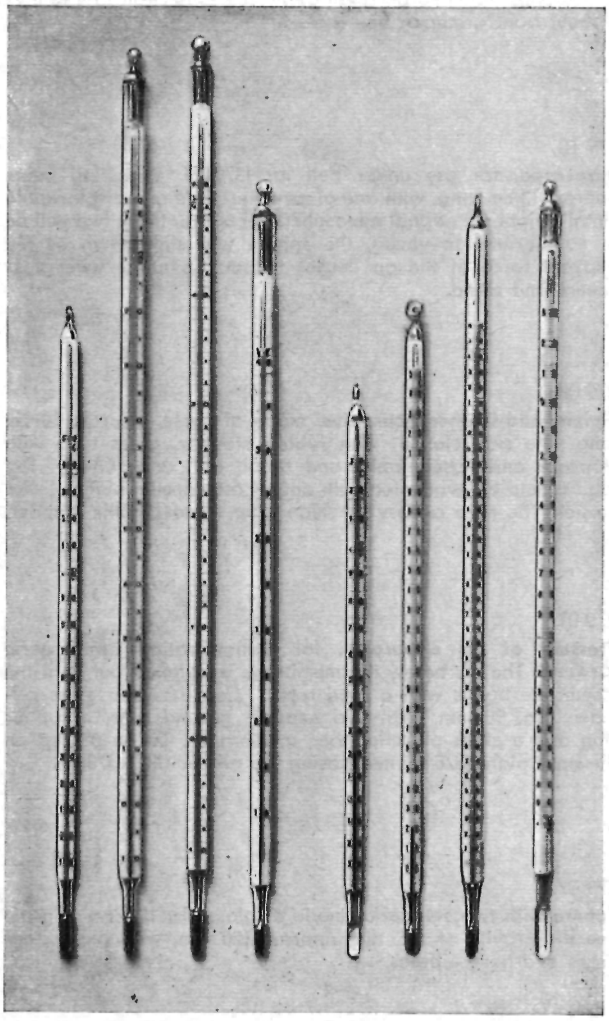
379 09

Pair of Magdeburg hemispheres, dia. approx. 120 mm, of iron; the two hemispheres can be put together vacuum-tight by interposing a rubber ring between their smoothly polished flanges. It is unnecessary to grease the joint. With shut-off and air inlet valves, hose nipple and one handle on each side, but without rubber tube.

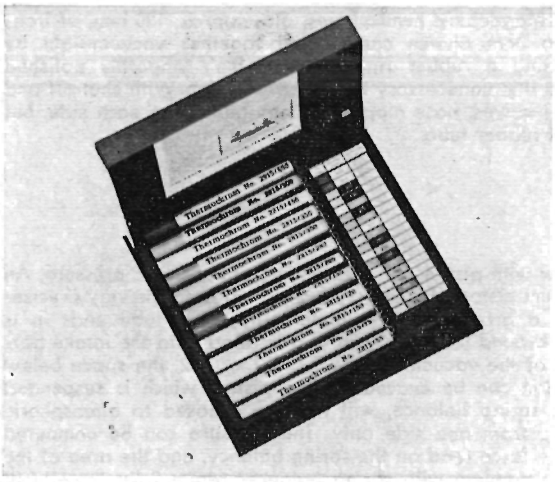
379 25

Cylinder with piston, for determining atmospheric pressure. An aluminium piston of 2 cm² cross-sectional area fits very precisely into a ground glass cylinder. The glass tube ends in a female ground joint NS 19/38. If it is fitted onto the intake port of one of the vacuum pumps S 1, D 1 or D 2, the space below the piston can be evacuated. The piston, which is suspended from a spring balance, will then be exposed to atmospheric pressure from one side only. The pressure can be computed from the force read on the spring balance, and the area of the piston. Complete with spring balance; range 2 kp (kg wt) but without stand.

Thermometers


382 33 / 34 / 35 / 36 382 47 / 48 / 49 382 82

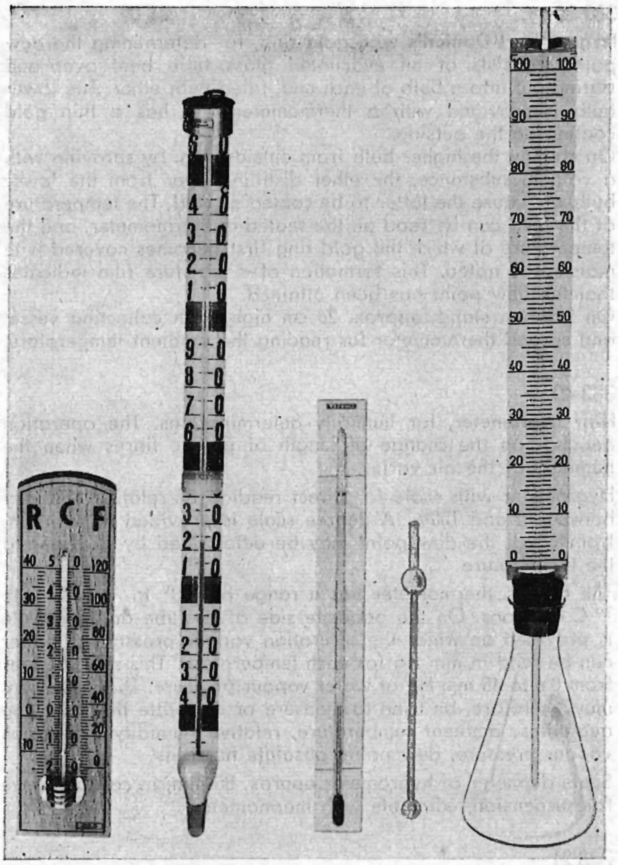
Cat. No. and description	Range °C	Div. °C	Approx. length cm
382 33 **Thermometer** of standard Jena glass, with opal glass scale and Richter-type scale mounting, mercury filling and yellow-lined capillary tube with bulb, approx. 8 to 10 mm dia.	–10 . . . +150	1°	25
382 34 **Thermometer,** same design	–10 . . . +110	1/5°	40
382 35 **Thermometer,** same design	–10 . . . +50	1/10°	45
382 36 **Thermometer,** same design	–10 . . . +40	1/5°	30
382 47 **Thermometer,** made of standard Jena glass (chemical thermometer) with sealed-in opal glass scale, glass eye, mercury filling, and yellow-lined capillary tube, approx. 8 to 10 mm dia.	–30 . . . +130	1°	25
382 48 **Thermometer,** same design	–10 . . . +250	1°	30
382 49 **Thermometer,** same design	–10 . . . +360	1°	30
382 82 **Thermometer for low temperatures,** made of Jena glass, with opal glass scale and Richter-type scale mounting, pentane filling, and blue-reflecting capillary tube.	–200 . . . +30	1°	30



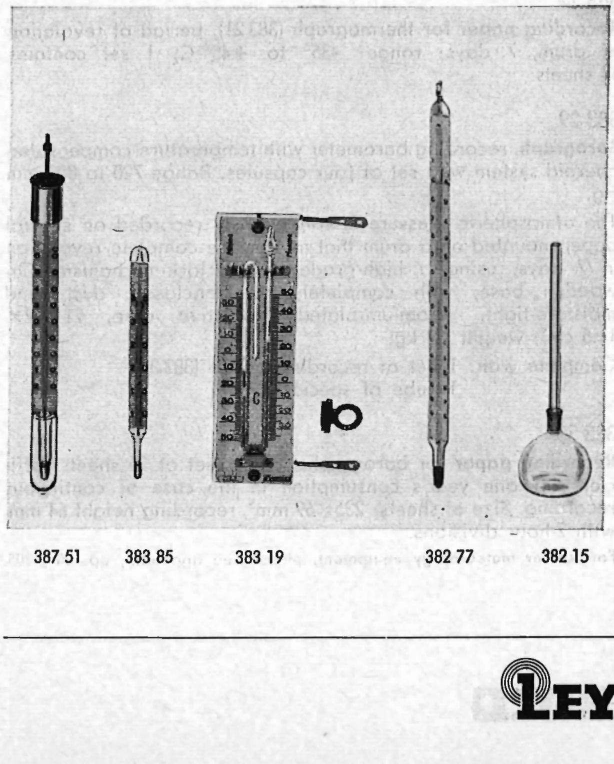
382 95

382 95

Set of 12 thermochrome crayons, in box. Temperature-sensitive crayons for determining and controlling temperatures between 64° and 600° C. Marks made with any one of these crayons will change colour from a certain temperature onwards, so that the temperature to be determined can be given an upper and a lower limit separated by a conveniently small amount.



382 51 382 41 382 25 382 23 382 02



387 51 383 85 383 19 382 77 382 15

382 02

Thermometer model, made of glass; consists of a glass tube with scale, approx. 50 cm long, and a glass flask with rubber stopper. When filled completely with coloured water, it will demonstrate the mode of action of a thermometer very clearly.

382 23

Thermometer tube for making your own thermometer. Capillary tube with two bulbs, open at the top, suitable for pouring in mercury.

382 25

Thermometer tube on opal glass plate. Instead of a scale, this thermometer is provided with a washable opal glass plate on which a graduation can be marked after determining the position of the fixed points. Overall length approx. 30 cm.

382 41

Large demonstration thermometer. Liquid-filled thermometer, approx. 50 cm long; range from –60° to +160° C, with 5° C divisions; with one coloured region every 50°. Easy to read from long distances and therefore particularly suitable for demonstrations.

382 51

Wall thermometer, with Réaumur, Centigrade and Fahrenheit scales. Ranges –10° to +40° R, divided in 1°; –20° to +50° C, divided in 1°, and 0° to +120° F, divided in 2°; on varnished wooden board, approx. 250×60 mm² in size, with eye for suspension and coloured filling.

382 15

Dilatometer, for determining the density and measuring the change of volume of a liquid as a function of temperature; suitable for quantitative investigations. Spherical vessel, capacity approx. 50 cm³, with glass capillary tube, 12 cm long, with millimetre graduation and ground glass joint.

382 77

Projection thermometer, approx. 22 cm long, range –50° to +100° C, with 1° divisions; transparent, projectable scale and metal cap with eye. Suitable for use in large lecture halls. For projection we recommend the projection arrangement shown in Fig. 36 on p. 72, or the Leitz projectors PRADO (442 50/51) and "pradovit" (442 91/93).

383 19

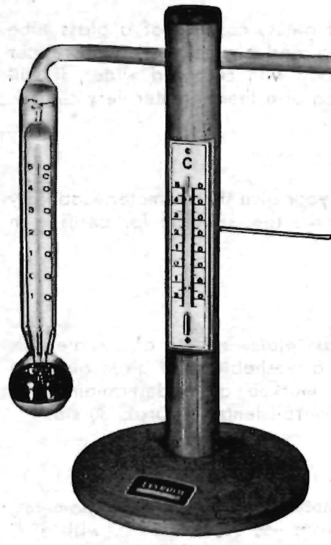
Maximum and minimum thermometer, on bevelled opal glass plate, with scale (upright and inverted), degrees below zero marked red, degrees above zero marked black. Range –30° to +50° C, with 1° C divisions, complete with magnet and brass holders for mounting, approx. 20 cm long.

383 85

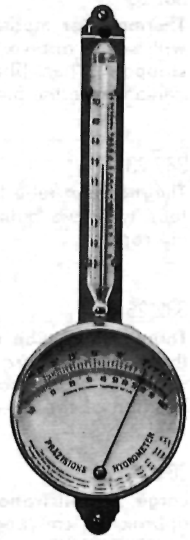
Spare thermometer, for mechanical equivalent of heat apparatus (388 14, cf. p. 59), range –10° to +40° C, approx. 17 cm long.

387 51

Freezing point thermometer, for demonstrating the variation of temperature during freezing, the supercooling of water and the latent heat of fusion of ice. The mercury bulb is surrounded by a sealed-on glass vessel half-filled with distilled water. Range –20° to +60° C, with 1° C divisions; total length approx. 22 cm, dia. of external vessel approx. 20 mm; with cork holder and metal cap.



383 32



383 40

383 32

Hygrometer, Daniell's with gold ring, for determining the dew point; consists of an evacuated glass tube bent over and flaring out into a bulb at each end, filled with ether. The lower bulb is provided with a thermometer and has a thin gold coating on the outside.

On cooling the higher bulb from outside, e.g. by spraying with a volatile substance, the ether distilling over from the lower bulb will cause the latter to be cooled as well. The temperature of the bulb can be read on the sealed-in thermometer, and the temperature at which the gold ring first becomes covered with moisture is noted. This formation of a moisture film indicates that the dew point has been attained.

On wooden stand, approx. 26 cm high, with collecting vessel and second thermometer for reading the ambient temperature.

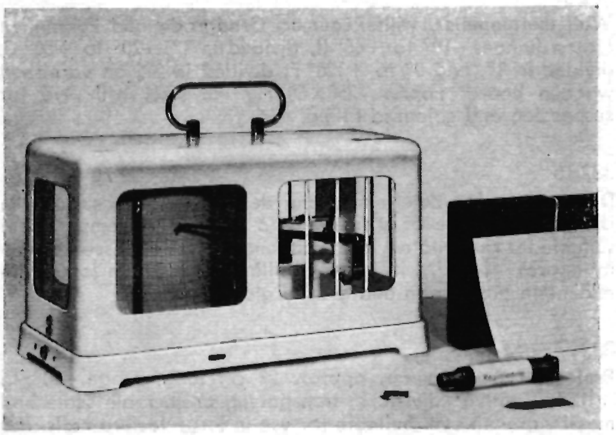
383 40

Hair hygrometer, for humidity determinations. The operation depends on the change of length of plastic fibres when the humidity of the air varies.

Hygrometer with scale for direct reading of relative humidity between 0 and 100%. A degree scale is provided in addition, from which the dew point may be determined by considering the temperature.

The built-in thermometer has a range of –30° to +50° C with 1° C divisions. On the opposite side of its tube another scale is provided on which the saturation vapour pressure of water can be read in mm Hg for each temperature. This scale ranges from 0.6 to 45 mm Hg of water vapour pressure. The instrument may, therefore, be used to measure or calculate the following quantities: ambient temperature, relative humidity, saturation vapour pressure, dew point, absolute humidity.

Scale diameter of hygrometer approx. 80 mm, in case with eye for suspension, complete with thermometer.



383 21

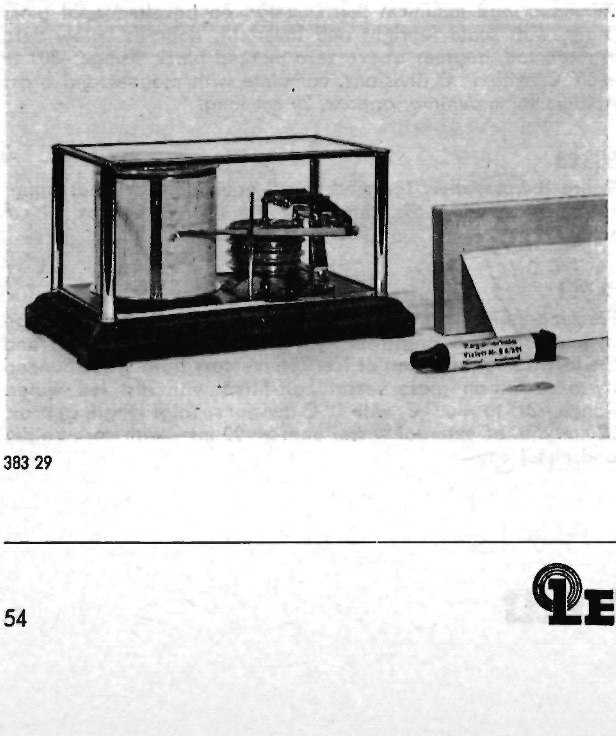
383 21

Thermograph, with corrosion-resistant finish, with high-grade bimetallic strip; normal range –35° to +45° C, (other temperature ranges on request), accuracy ±0.2°, in metal case, white varnish finish, other parts high-gloss chromium-plated. Drum takes 7 days for one revolution (displacement: 40 mm per day); dimensions 28×14×17 cm³; complete with:

1 Set of recording paper (383 22)
1 Tube of special ink
1 Spare pen
1 Metal foil for cleaning

383 22

Recording paper for thermograph (383 21), period of revolution of drum, 7 days; range: –35° to +45° C; 1 set contains 54 sheets.



383 29

383 29

Barograph, recording barometer with temperature-compensated aneroid system with set of four capsules. Range 720 to 800 mm Hg.

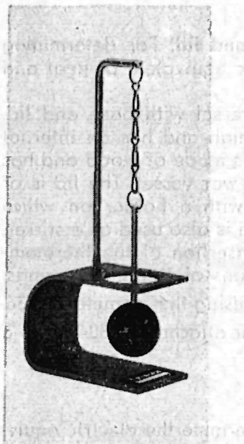
The atmospheric pressure is continuously recorded on special paper mounted on a drum that makes one complete revolution in 7 days, using a high-grade 8-day clock-mechanism. On wooden base, with completely glass-enclosed, dust- and moisture-tight, chromium-plated protective case, 21×12×11.5 cm³; weight 1.3 kg.

Complete with: 1 Set of recording paper (383 30)
1 Tube of special ink

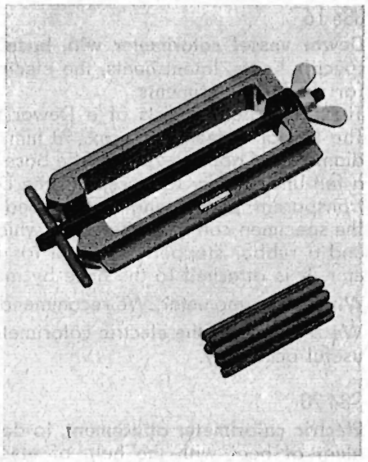
383 30

Recording paper for barograph (383 29); set of 55 sheets sufficient for one year's consumption in the case of continuous recording. Size of sheets: 235×69 mm², recording height 64 mm, with 2-hour divisions.

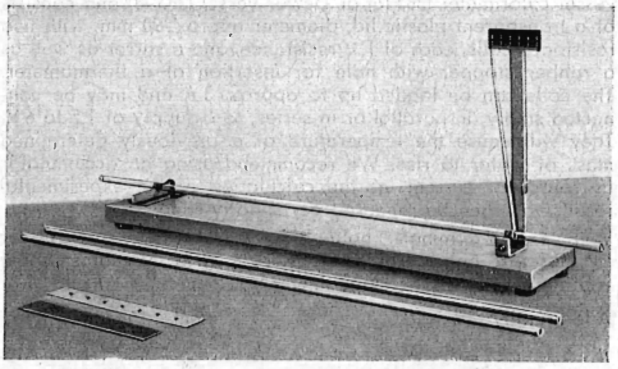
For further meteorology equipment, please see appendix, pp. 204, 205.



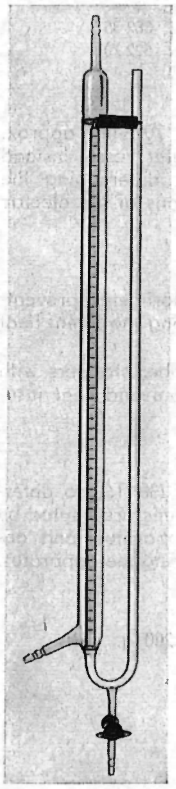
381 01



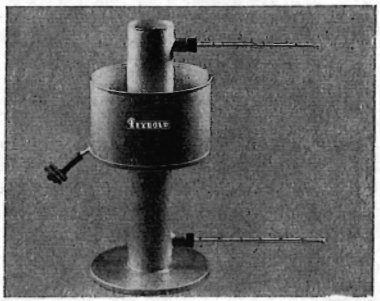
381 16



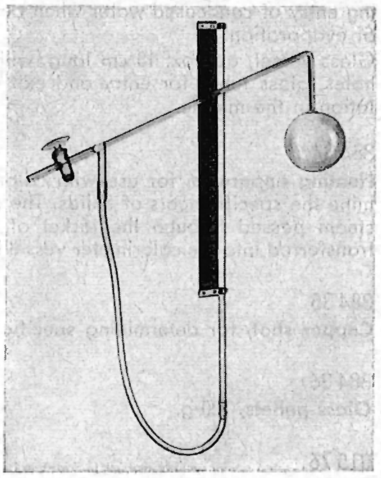
381 32 381 34



381 56



381 47



381 59

381 01
Ball and ring, for demonstrating thermal expansion. The ball is suspended from a stand and will pass easily through the ring when cold. Approx. 18 cm high. Cf. LEYBOLD Physics Leaflets DC 536.413.2; a.

381 16
Tyndall's bar-breaker gives a very impressive demonstration of the large stresses set up in a solid by a change of temperature if the change of length associated with it is resisted.
With the apparatus assembled as shown, the steel bar in the centre is heated with a Bunsen burner and the winged nut used to take up the slack (1/2 to 3/4 of a turn). When the burner is removed and the bar allowed to cool down, the bolt will break. Size of cast-iron frame approx. 21×10 cm^2. Complete with 10 cast-iron bolts, without burner.

Parts for use as accessories:

1 Tripod	303 52
1 Teclu burner	303 07

381 17
1 Set of 10 spare bolts for Tyndall's bar-breaker (381 16).

381 32
Pair of bimetallic strips, each 20 cm long, which will bend when heated or cooled. One of the bimetallic strips consists of two pieces of sheet-metal riveted together and permits the arrangement of such a strip to be recognised very clearly. The other one is the technical embodiment of the principle and consists of pieces of sheet-metal rolled together.

381 34
Expansion apparatus, for determining the coefficient of linear expansion of iron, copper or glass tubes through which steam is passed to heat them to approximately 100° C.
A rigid and a movable knife-edge are mounted on a baseboard and spaced 50 cm apart. The movable knife-edge is connected to a long pointer, which shows the enlarged expansion on a scale.
Complete with tubes of iron, copper and glass, but without steam generator.

381 47
Hope's apparatus for demonstrating the maximum density of water. Sheet-metal cylinder, approx. 33 cm high, with cooling trough for filling with cooling mixture and holes for inserting thermometers. If the outer trough is cooled, water of +4° C will collect at the bottom of the inner cylinder.
Complete with 2 thermometers and rubber stoppers.

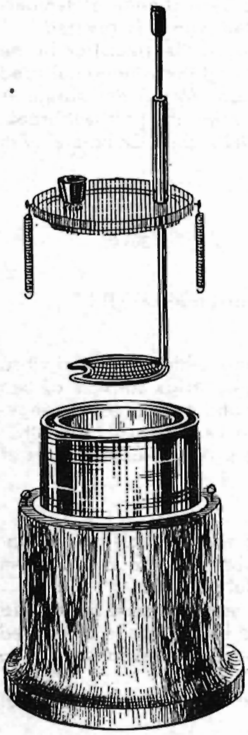
381 56
Constant-pressure air thermometer. Glass tube, U-shaped, sealed at one end, arms 56 cm long, with graduation, draining cock and heating jacket. The volume of air enclosed in the upper, sealed arm by the mercury is heated to 100° C by steam and then returned to its original pressure by draining off mercury; the final volume so obtained is measured. Supplied without steam generator and mercury.

381 59
Constant-volume air thermometer. The volume of air enclosed in a sphere with capillary tube is heated in a water bath and restored to its original volume by raising the mercury level. The pressure so obtained is measured. Complete with draining stopcock, rubber tube, manometer tube and scale, 28 cm long, but without stands, mercury, warm water bath and thermometer.

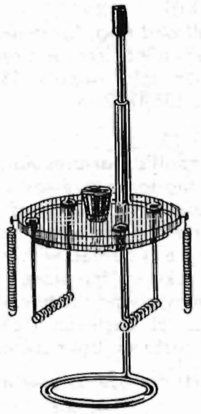
Additionally recommended for setting up:

	For 381 56	For 381 59
Stand base	300 01	300 02
Stand rod	300 43	300 43
Leybold boss	301 01	2×301 01
Bunsen clamp	302 63	2×302 62
Mercury	177 21	177 21
Ancillary equipment for work with mercury (cf. page 10)		

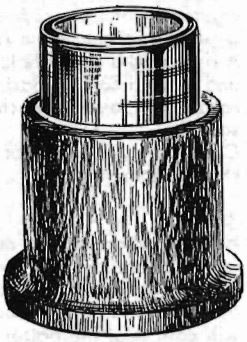
See also "LEYBOLD Physics Leaflets", DC 536.411-36; a and DC 536.411-37; a



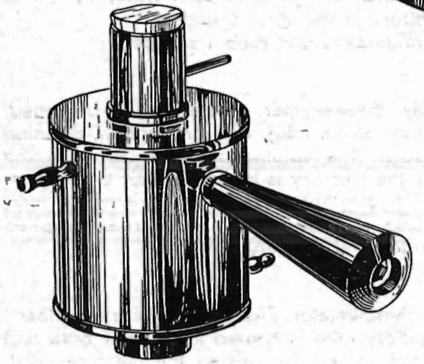
384 16



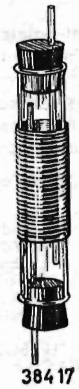
384 20



386 48



384 34



384 17

384 16

Dewar vessel calorimeter with base and lid. For determining specific heats, latent heats, the electric equivalent of heat and for similar experiments.

The apparatus consists of a Dewar vessel with base and lid. The Dewar vessel is approx. 90 mm high and has an internal diameter of approx. 70 mm. The base is made of wood and has a felt-lined cavity for receiving the Dewar vessel. The lid is of transparent plastic and is provided with a holder on which the specimen can be placed, and which is also used as a stirrer, and a rubber stopper with hole for insertion of the thermometer. It is attached to the base by means of a pair of springs.

Without thermometer. We recommend using thermometer 382 36.

We recommend the electric calorimeter attachment (384 20) as a useful accessory.

384 20

Electric calorimeter attachment, to determine the electric equivalent of heat with the help of electrically heated resistance coils immersed in a Dewar vessel. The attachment fits Dewar vessel calorimeter (384 16) or Dewar vessel (386 48) and consists of a transparent plastic lid, diameter approx. 90 mm, with two resistance coils, each of 1 Ω resistance, and a stirrer as well as a rubber stopper with hole for insertion of a thermometer. The coils can be loaded up to approx. 3 A and may be connected singly, in parallel or in series, to a supply of 1.5 to 6 V. They will cause the temperature of a previously determined mass of water to rise. We recommend using an accumulator as source of current, as the calculation of the experimental results will then be rendered particularly simple.

With 4 mm-terminals, holding springs, stirrer and rubber stopper with one hole for the insertion of a thermometer, but without Dewar vessel, thermometer and source of current.

Additionally required:

1 Dewar vessel	386 48
or	
1 Dewar vessel calorimeter	384 16
and	
1 Thermometer	382 35
1 Accumulator	522 70

386 48

Dewar vessel with base, int. dia. approx. 70 mm, approx. 90 mm high, without lid. For use as calorimeter vessel instead of Dewar vessel calorimeter (384 16) when determining the electro-mechanical equivalent of heat by means of the electric calorimeter attachment (384 20).

384 17

Water separator, as trap for use with the calorimeter, preventing entry of condensed water when determining the latent heat of evaporation.

Glass vessel, approx. 18 cm long, with 2 rubber stoppers with holes, glass tubes for entry and exit of steam and heat insulation in the middle.

384 34

Heating apparatus, for use with calorimeter (384 16), to determine the specific heats of solids. The specimens are heated by steam passed through the jacket of the apparatus, and are transferred into the calorimeter vessel by turning the apparatus.

384 35

Copper shot, for determining specific heat, 200 g.

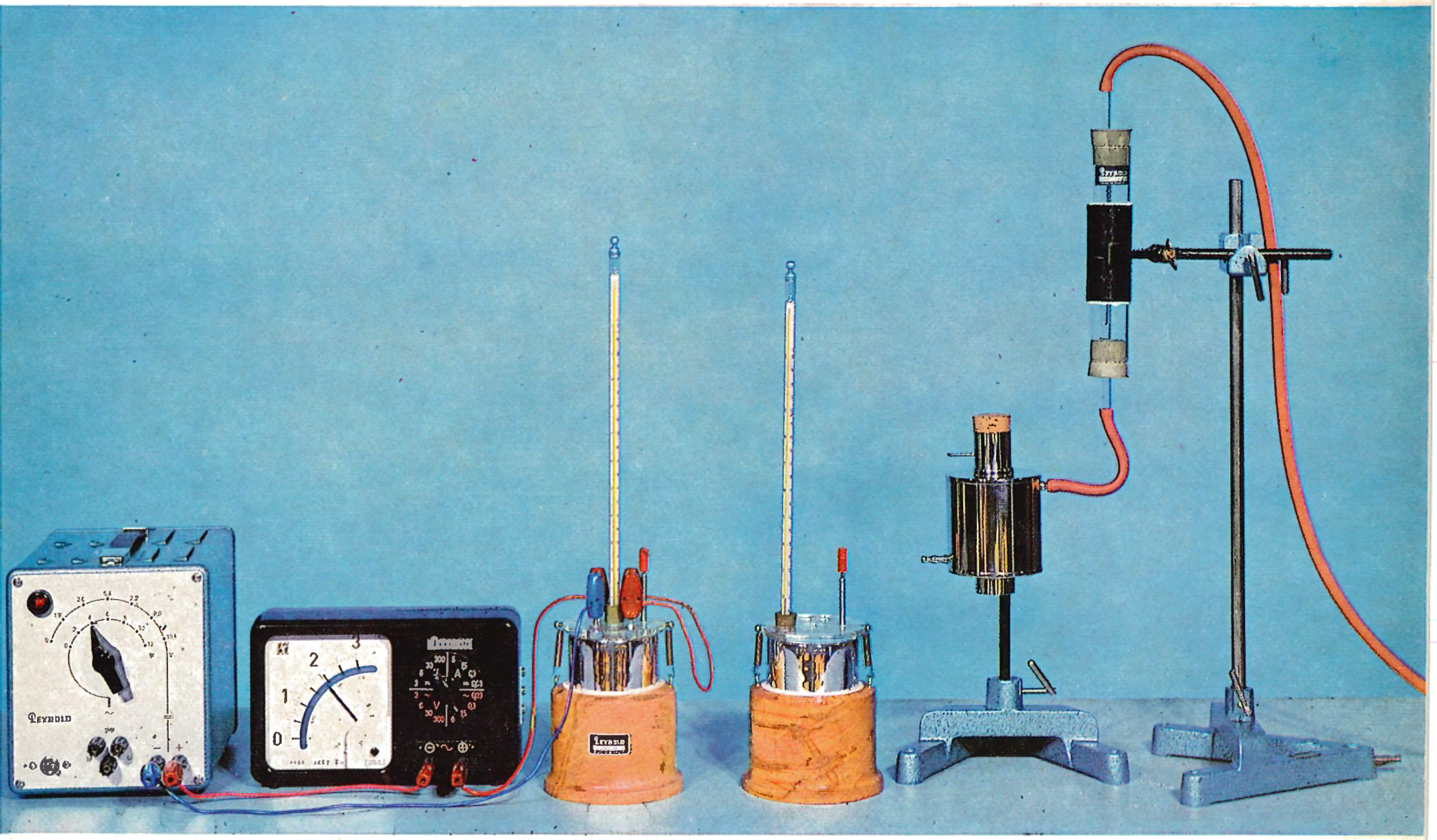
384 36

Glass pellets, 100 g.

315 76

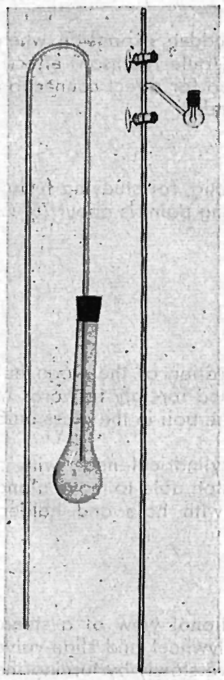
Lead shot, 200 g, dia. of pellets approx. 3 mm, in plastic bottle.

LEYBOLD

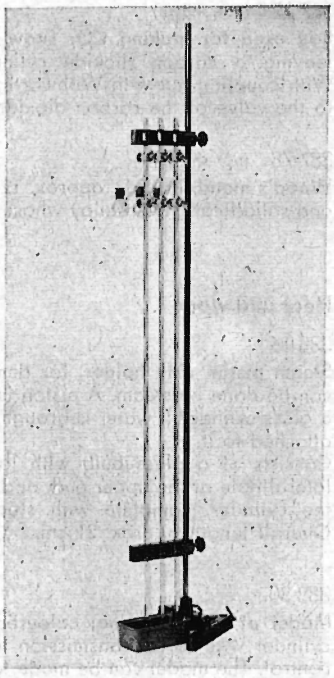


The electrical equivalent of heat
and the specific heats of solids
are determined in the same Dewar vessel
using different tops.

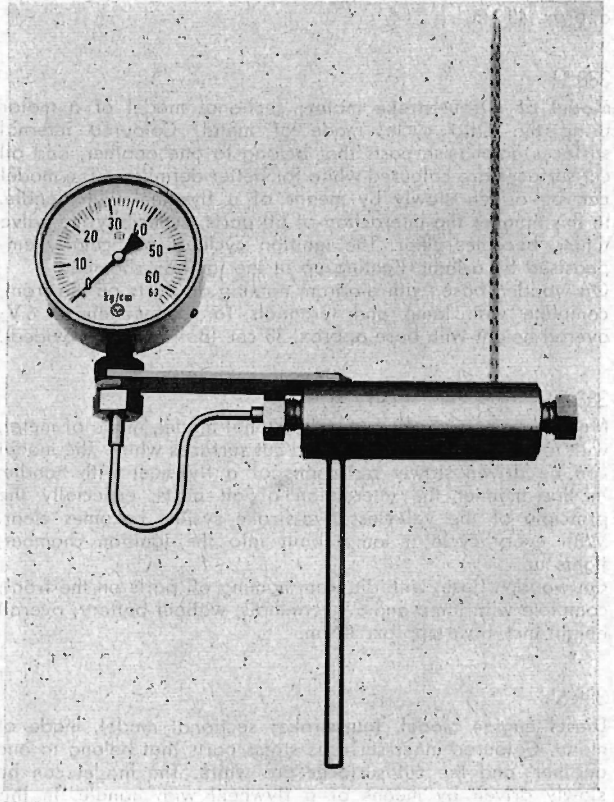
PLATE III



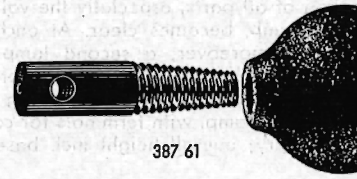
385 10 385 08



385 09



385 16



387 61

385 09

Vapour pressure apparatus, for measuring the vapour pressure of liquids by means of a mercury column. The measuring principle is very simple: a Torricellian tube dips into a mercury-filled trough at the bottom and is evacuated at the top till the mercury column indicates the atmospheric pressure. A sample of a liquid is then brought into the vacuum. Its vapour pressure acts upon the mercury column from above and causes it to fall by a corresponding amount. It is possible to make comparative determinations with 3 liquids at a time. The apparatus consists of 3 measuring tubes, approx. 98 cm long, each with 2 cocks and a storage vessel, 2 wooden bars with clamping screws and holders for 3 tubes, 1 mercury trough and stands, including 1 stand base, length of sides 20 cm, and 1 stand rod 120 cm long, but without mercury; approx. 1.5 kg are needed.

385 08

Vapour pressure tube, spare tube for vapour pressure apparatus (385 09); the tube may also be used singly to measure the vapour pressure of a liquid.

385 10

Boiling flask with rising tube, for determining the vapour pressure curve of water between the boiling point and room temperature. Water is brought to the boil in the flask. Before removing the source of heat and letting the flask cool, the open end of the rising tube is immersed in a mercury-filled trough. As the vapour pressure of the water decreases on cooling, the mercury column will ascend in the rising tube.

Complete with one glass flask, stopper with hole and a U-shaped glass tube with approx. 90 cm long arms.

Additionally recommended:

1 Thermometer	382 47
1 Bunsen burner	303 03
1 Mercury trough	371 85
Mercury, 200 g . . . . from	177 21
Ancillary equipment for work with mercuy (cf. page 10)	
Stands	

385 16

High pressure steam boiler, for determining the vapour pressure curve of water up to approx. 250° C and an excess pressure of about 50 atmospheres. The pressure is generated in a metal cylinder of approx. 5 cm external diameter. The cylinder is provided with an axial bore for introducing a small quantity of water. The bore is connected with a high-pressure manometer. The thermometer is inserted into the radial bore.

Although the experiment can be continued up to relatively high pressures, it is completely safe due to the small volume of heated water.

Complete with manometer, range 0 to 60 atmospheres; thermometer reading up to 250° C, screw stopper and gaskets as well as holding rod for mounting in a stand base, but without stand base and Bunsen burner.

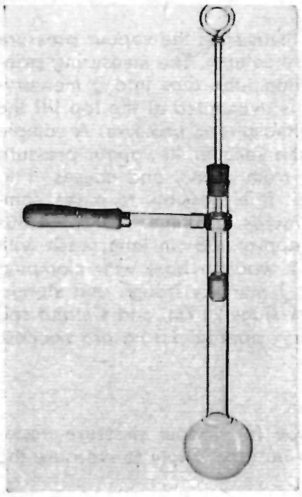
Change of state

387 61

Bursting bottle with screw stopper, for demonstrating the increase of volume of water on freezing. A very impressive demonstration: the cast-iron sphere will burst with a loud bang if it is completely filled with water, screwed up tightly and cooled with a cooling mixture or dry ice. Dia. approx. 60 mm, with 14 mm screw that can be tightened by means of a rod passed through the transverse hole.

387 62

Set of 5 spare spheres for (387 61), without screw stopper.



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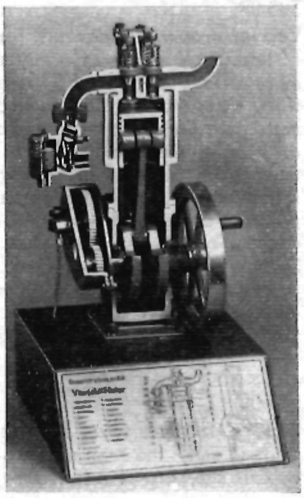
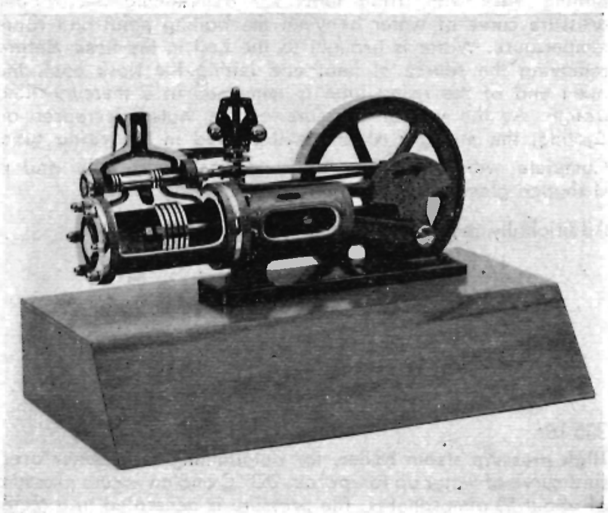


388 51



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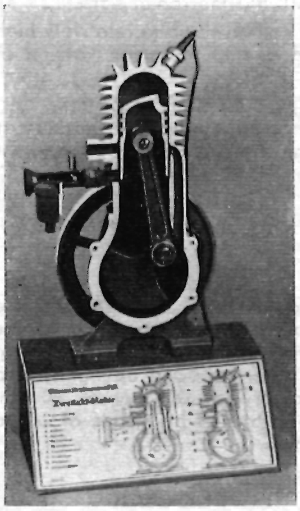
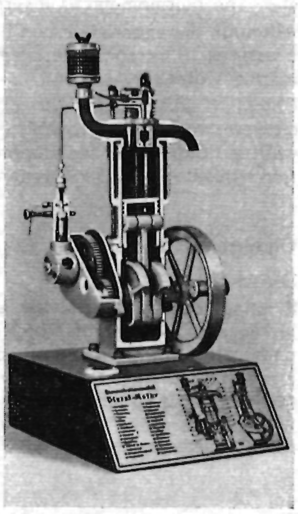


388 54



388 55

387 22 (not shown)
Bag used for making CO_2 snow by sudden expansion when leaving a carbon dioxide cylinder (Joule-Thomson effect). With coupling nut with Withworth thread for direct connection to the valve of the carbon dioxide cylinder.

387 78 (not shown)
Wood's metal, in rods, approx. 12 cm long, for studying fusion and solidification. An alloy whose melting point is about 75° C.

Heat and work

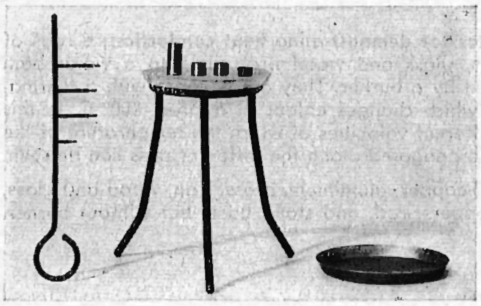
388 16
Steam piston with holder, for demonstration of the work that can be done by steam. A piston is pushed forcibly forwards in a glass cylinder if water is brought to the boil in the glass bulb attached to it.
Consists of a glass bulb with long, cylindrical neck, with a lateral hole at the upper end, and a piston able to move along the cylinder, complete with stopper with hole and holder. Overall length approx. 31 cm.

388 30
Model of steam engine; coloured sectional view of a steam cylinder with force transmission to a flywheel and slide-valve control. The model can be made to move slowly by turning the flywheel by means of a crank. In this manner the mutual interaction of the parts can be demonstrated. Overall length approx. 40 cm.

388 51
Model of a four-stroke motor; sectional model of a motor using the Otto cycle, made of metal. Coloured internal surfaces emphasise parts that belong to one another, and all cut surfaces are coloured white for better definition. The model can be driven slowly by means of a flywheel with handle. In this manner the interaction of all parts, especially the valve timing becomes clear. The ignition cycle is particularly emphasised by a lamp lighting up in the ignition chamber.
On wooden base, with diagram naming all parts on the front, complete with lamp and terminals for connection to 6 V; overall height with base approx. 38 cm. (Battery not provided).

388 54
Model of a two-stroke motor; sectional model, made of metal, with inner surfaces coloured and cut surfaces white. The model can be driven slowly by means of a flywheel with handle. In this manner the interaction of all parts, especially the principle of the valveless two-stroke system becomes clear. With every cycle a lamp, built into the ignition chamber, lights up.
On wooden base, with diagram naming all parts on the front; complete with lamp and 6 V terminals, without battery; overall height incl. base approx. 35 cm.

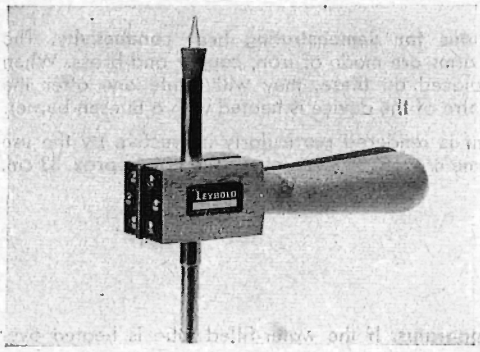
388 55
Diesel engine model, four-stroke; sectional model, made of metal. Coloured inner surfaces stress parts that belong to one another, and the cut surfaces are white. The model can be slowly driven by means of a flywheel with handle. In this manner the interaction of all parts, especially the valve timing and the fuel injector pump, becomes clear. At each cycle a built-in lamp lights up; moreover, a second lamp may be switched on by pressing a key to represent the preliminary heating. On wooden base, with a diagram naming all parts on the front; complete with lamp, with terminals for connection to 6 V; but without battery; overall height incl. base approx. 42 cm.



384 01

384 01

Tyndall's apparatus for comparing the specific heats of metals. Four heated metal cylinders of equal mass are placed on a paraffin wax plate and will sink to different depths and at different rates in the wax. This indicates different heat capacities and, on account of the equal masses, different specific heats.
Metal cylinders, of 25 g mass each, of iron, tin, lead and aluminium; with fork for simultaneous application of the cylinders, paraffin wax and tray for melting the paraffin wax, but without tripod.



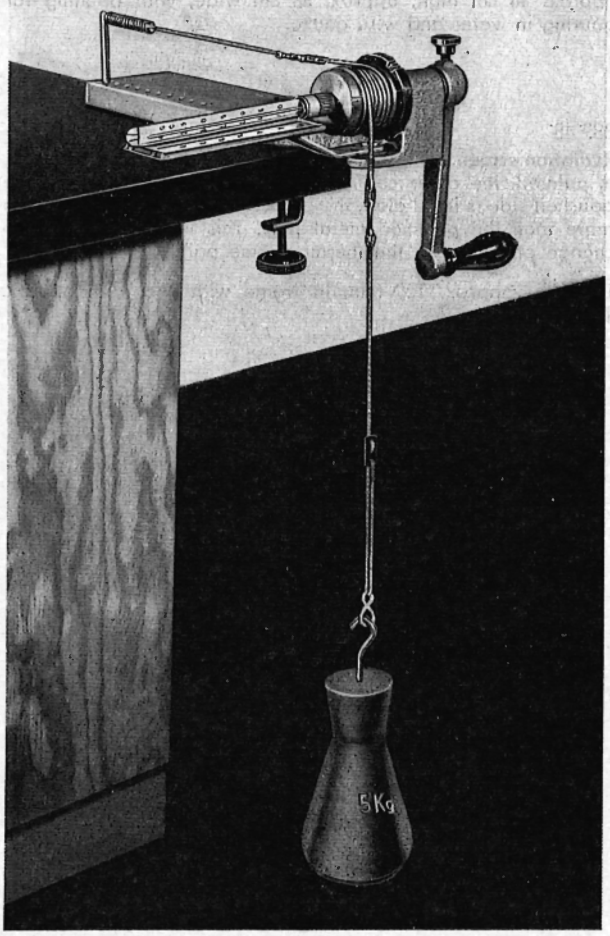
347 78

347 78

Tyndall's friction cylinder, Count Rumford's experiment. Metal tube mounted on a rod to fit the chuck of one of our rotators, and friction clamp. The rotating tube is heated from the outside by friction. This makes the ether in the tube boil and the vapour can be lit at the nozzle. Complete with friction clamp, stopper and nozzle, but without ether.
The apparatus should be used on centrifugal machine (347 15) or standard electric motor (347 25/26).

388 10

Tube and shot for rough determination of the mechanical equivalent of heat, tube, 1 m long, with cork stoppers, complete with 1 kg of lead shot, but without thermometer.



388 14 with 388 24

388 14

Mechanical equivalent of heat apparatus, designed by Schürholz and Sprenger. Clear and easily comprehensible apparatus which has also proved very valuable in practical work by students. When the readings are taken with proper care, an accuracy of 2% is achieved.

In the course of the experiment, mechanical energy is continuously transformed into heat. The mechanical energy is produced by turning a copper calorimeter against the friction force of a copper band. Due to the particular construction of the apparatus, this friction force is constant and independent of the frequency with which the calorimeter is turned. It is easy to measure because it is in equilibrium with a 5 kg weight. The heat produced can be measured using the rise in temperature of the calorimeter; the thermometer can be read free from parallax by means of a plane mirror.

The copper is highly durable, easy to fit and keeps the calorimeter polished during operation. The low heat losses in this apparatus enable elementary determinations to be made quite accurately without cooling corrections.

The apparatus is supplied complete with base board, crank, calorimeter, thermometer, copper band and suspension. One weight with hook, 5 kg (388 24), is additionally required.

See also "LEYBOLD Physics Leaflets", DC 536.721; a and b.

388 24

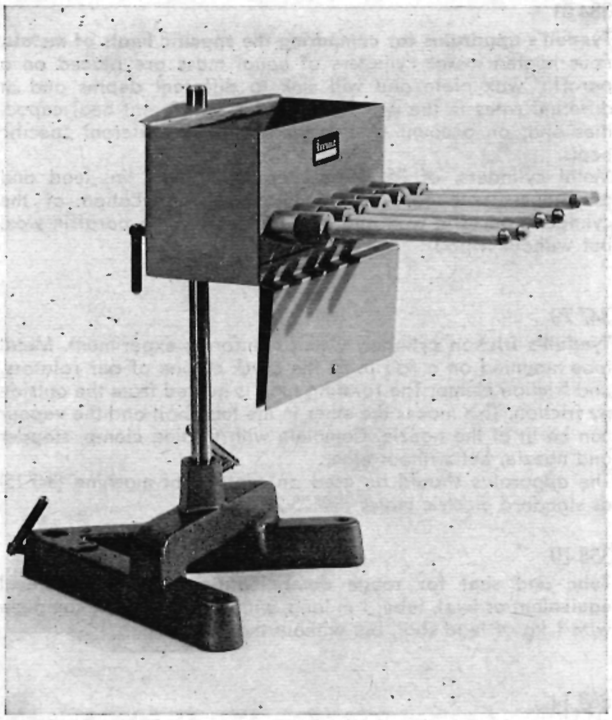
Weight with hook, 5 kg, iron, varnished.

383 85

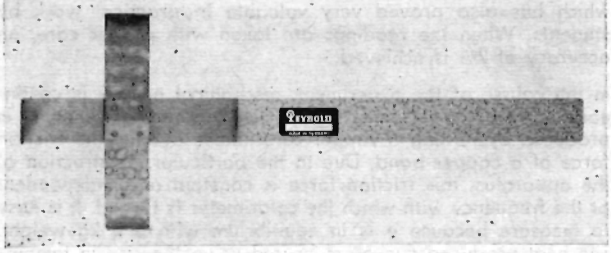
Spare thermometer, for mechanical equivalent of heat apparatus (388 14), range –10° to +40° C, approx. 17 cm long.

388 15

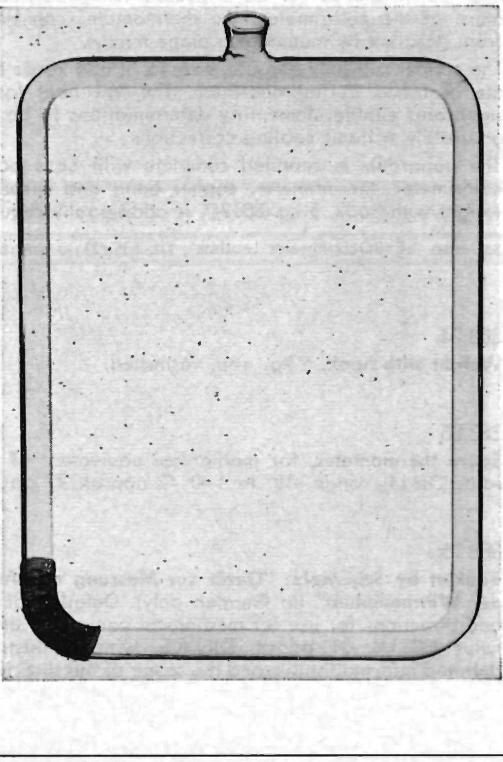
Booklet by Schürholz: "Gerät zur Messung des Arbeitswertes der Wärmeeinheit" (in German only). Detailed description of and directions for use for mechanical equivalent of heat apparatus (388 14). 21 pages, DIN A 5, with 8 illustrations. For detailed information beyond the scope of the directions for use.



389 03



389 10



389 18

389 03

Large apparatus for demonstrating heat conduction; 6 rods of various metals, glass and wood protrude into a water bath which is heated by a burner. They are covered with a thermochrome paint which changes colour at approx. 100° C. In this manner the different velocities at which the temperature of the water bath is propagated along the different rods can be seen.

With 6 rods of copper, aluminium, brass, iron, wood and glass, as well as stoppers, rod, and stand base, but without burner.

389 10

Simple apparatus for demonstrating heat conductivity. The three notched arms are made of iron, copper and brass. When matches are placed on these, they will ignite one after the other if the centre of the device is heated with a Bunsen burner.

The experiment is rendered particularly instructive by the use of thermochrome crayons (382 95); overall length approx. 33 cm.

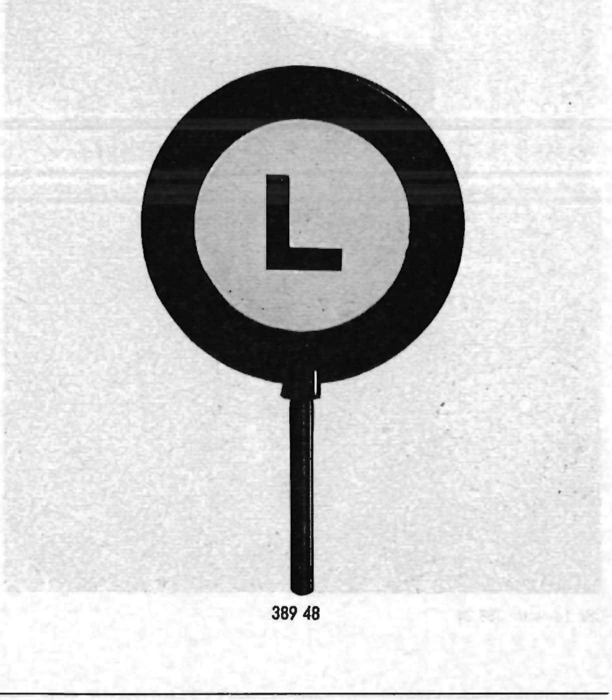
389 18

Convection apparatus. If the water-filled tube is heated over the Bunsen burner at the wire-gauze protected corner, a circulation due to convection will be produced which can be made visible by the use of a dye. Rectangularly bent glass tube, approx. 44 cm high, approx. 33 cm wide, with opening for pouring in water and wire gauze.

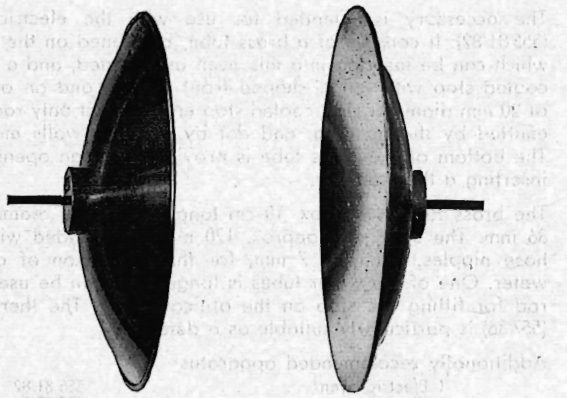
389 48

Radiation screen. One side polished metal on which a black "L" is painted, the other coated with thermochrome paint. If the polished side is irradiated, the blackened part of it will heat up more than the polished metal part. This is indicated by the change of colour of the thermochrome paint.

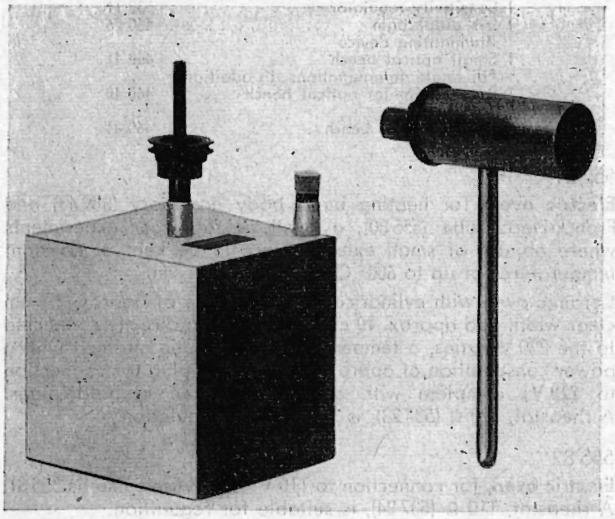
Diameter approx. 120 mm, in frame with rod, dia. approx. 10 mm.



389 48

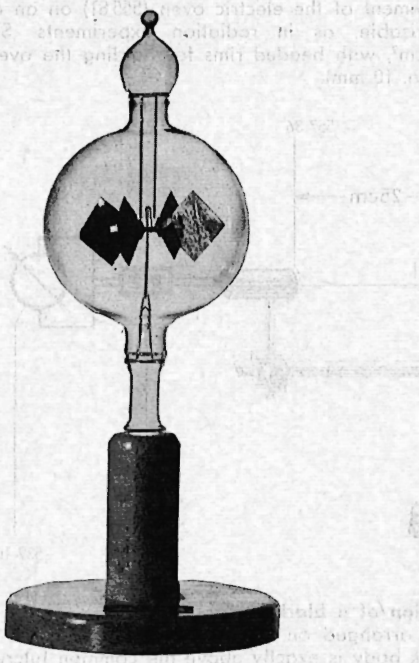


389 24



389 26 with 389 28

557 36



389 86

389 24

Pair of concave mirrors, for experiments on radiant heat and acoustics; dia. 390 mm, focal length approx. 160 mm. These values are particularly convenient in both fields of application. The inner surfaces of the mirrors are polished; therefore the foci can be determined optically with the help of small lamps and the adjustment carried out in this manner, subsequently replacing the lamps by the sources of heat or sound. This removes all the difficulties that are otherwise bound up with the adjustment.

Complete with rods (dia. 10 mm) but without stands. Particularly suitable for arrangement on an optical bench or on two separate stands consisting of:

1 Stand base	300 01
1 Pair of levelling screws	300 06
1 Stand rod, 50 cm long	300 42
1 Leybold boss	301 01

389 26

Leslie's cube, for studying the dependence of thermal radiation upon the nature, temperature and distance of the radiant surface. Of the 4 lateral surfaces of the cube, one is of polished metal, the second of dull metal, the third is covered with white and the fourth with black varnish. For the measurements, the cube is filled with hot water; two openings, one for introducing a thermometer, the other for introducing a stirrer, are provided. Edges approx. 10 cm long, without stirrer and thermometer.

For exact measurements we recommend using thermopile (557 36), but for the qualitative experiments the double thermoscope (391 01) with the plane ground capsules (391 07) may also be used.

389 28

Stirrer for Leslie's cube, with cord pulley.

389 86

Radiometer. A rotor with vanes covered with lamp-black on one side is arranged inside an evacuated glass bulb. When exposed to radiation, the rotor will turn, because the residual air molecules impinging on the black surfaces are reflected with a higher velocity than those impinging on the polished surfaces, and therefore the recoil energy they impart to the vanes is greater. Glass bulb, approx. 80 mm dia., on base.

557 36

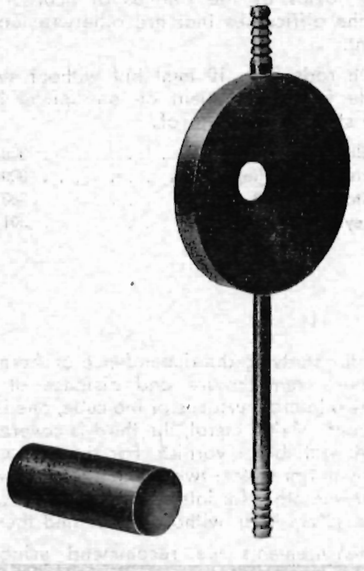
Moll's thermopile, sensitive instrument for measuring radiant energy, e.g. the thermal radiation of a black body or Leslie's cube, or for determining the spectral energy distribution or exploring diffraction patterns. Over an area of 10 mm diameter, the thermopile contains 16 linearly arranged konstantan-manganin thermocouples, silver-soldered and blackened on the front; complete with 4 mm terminals, on rod (dia. 10 mm).

Sensitivity: approx. 0.16 mV/mW, internal resistance approx. 10 Ω, response time 2–3 seconds. In massive metal case, 8 cm long, dia. approx. 35 mm, with polished funnel, aperture angle: 22°. The front opening of the funnel is closed with a glass window which should be taken out when measuring thermal radiation.

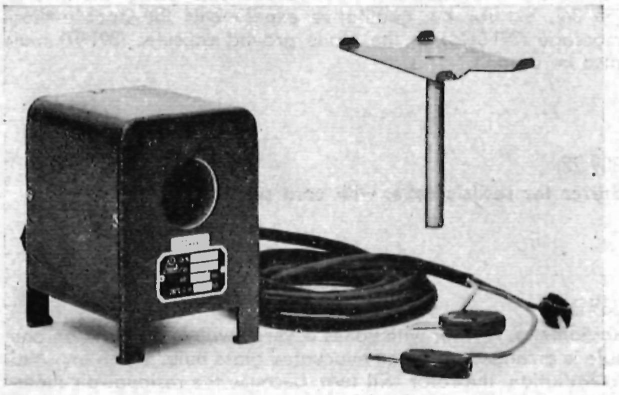
As an indicating instrument we recommend school mirror galvanometer (532 10) with sensitivity regulator (532 11).

389 43

Black body accessory, for thermal radiation experiments, which belong to the fundamental experiments of physics: e.g. measurement of the intensity of radiation as a function of temperature, distance, and angle and for comparison with other radiating objects of the same temperature, which are not black bodies.



389 43



555 81 555 82 555 84

The accessory is intended for use with the electric oven (555 81/82). It consists of a brass tube, blackened on the inside, which can be inserted into this oven and heated, and a water-cooled stop with funnel-shaped front surface and an opening of 20 mm diameter. The cooled stop ensures that only radiation emitted by the opening, and not by the side walls emerges. The bottom of the brass tube is provided with an opening for inserting a thermometer.

The brass tube is approx. 10 cm long, and has a diameter of 36 mm. The stop, dia. approx. 120 mm, is provided with two hose nipples, ext. dia. 7 mm, for the circulation of cooling water. One of the water tubes is longer and can be used as a rod for fitting the stop on the optical bench. The thermopile (557 36) is particularly suitable as a detector.

Additionally recommended apparatus:

1 Electric oven	555 81/82
1 Rheostat	537 23/24
1 Support for electric oven	555 84
1 Thermopile	557 36
1 School mirror galvanometer	532 10
1 Sensitivity regulator	532 11
1 Iris diaphragm	460 26
Illuminating device	
1 Small optical bench	460 41
For angle determinations, in addition:	
1 Swivel joint for optical bench	460 40
and one more	
Small optical bench	460 41

555 81

Electric oven, for heating black body accessory (389 43) and Franck-Hertz tube (555 80), as well as for other experiments where objects of small extension are to be kept at constant temperatures of up to 600° C.

Ceramic oven with cylindrical heating space of approx. 37 mm clear width and approx. 10 cm length. When directly connected to the 220 V mains, a temperature of 600° C is attained with a power consumption of approx. 200 W. With plug for connection to **220 V**; complete with cable with three Leybold plugs. A rheostat, 320 Ω (537 23), is suitable for regulation.

555 82

Electric oven, for connection to 110 V; otherwise same as 555 81. A rheostat, 110 Ω (537 24), is suitable for regulation.

555 84

Support for electric oven, for all experiments where the arrangement of the electric oven (555 81) on an optical bench is advisable, as in radiation experiments. Size: approx. 11×6 cm², with beaded rims for holding the oven, and stand rod (dia. 10 mm).

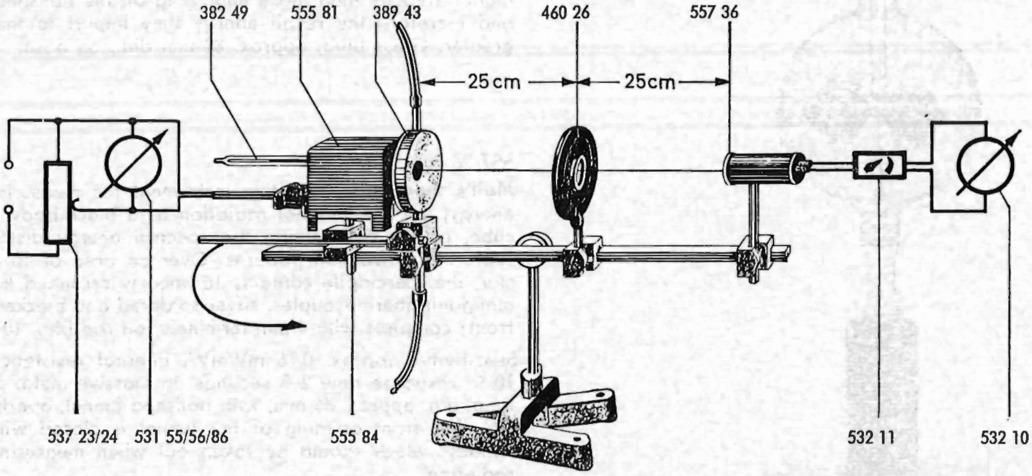
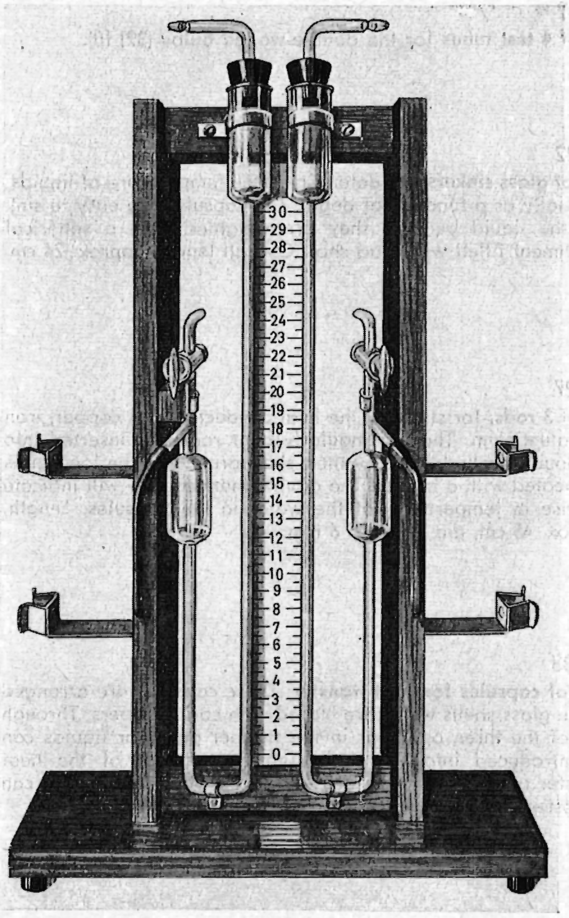


Fig. 28 **Intensity distribution of the thermal radiation of a black body.** Black-body accessory and thermopile are arranged on an optical bench so as to be capable of swivelling. The stop of the black body is exactly above the common fulcrum.



391 01

391 01

Double thermoscope designed by Looser. This apparatus is essentially a sensitive double manometer and can, therefore, be used for many experiments in the study of heat and for numerous other experiments. The readings are clearly visible from both back and front of the instrument. Both the class and the teacher can simultaneously read off the rise and fall of the two liquids and the difference on the scale. The design as a double instrument has the advantage that absolute determinations are not necessary and relative measurements can be made, whose accuracy is surprisingly great.

A number of accessories, which are listed below, will facilitate the taking of important measurements.

On frame, approx. 56 cm high, scale, approx. 50 cm long. The two manometers are U-shaped and provided with receptacles at either end. The short arms have stopcocks pressure equalisation and are provided with hose nipples and rubber tubes for connecting the probes.

Complete with manometer liquid, without probes and accessories.

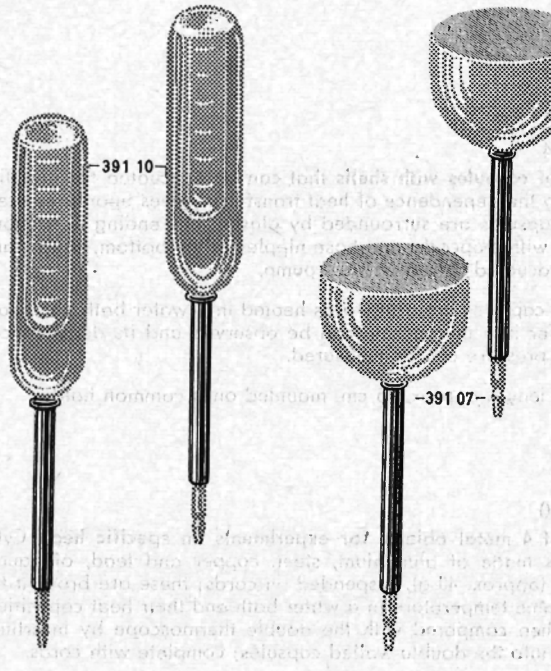
Accessories to the double thermoscope

391 15

Manometer fluid, coloured; of low vapour pressure; for refilling double thermoscope (391 01) and universal manometer (373 66); bottle holding 100 cm³.

391 14

Cleaner, wooden rod, 30 cm long, round which is wrapped in exchangeable filter paper.



391 07

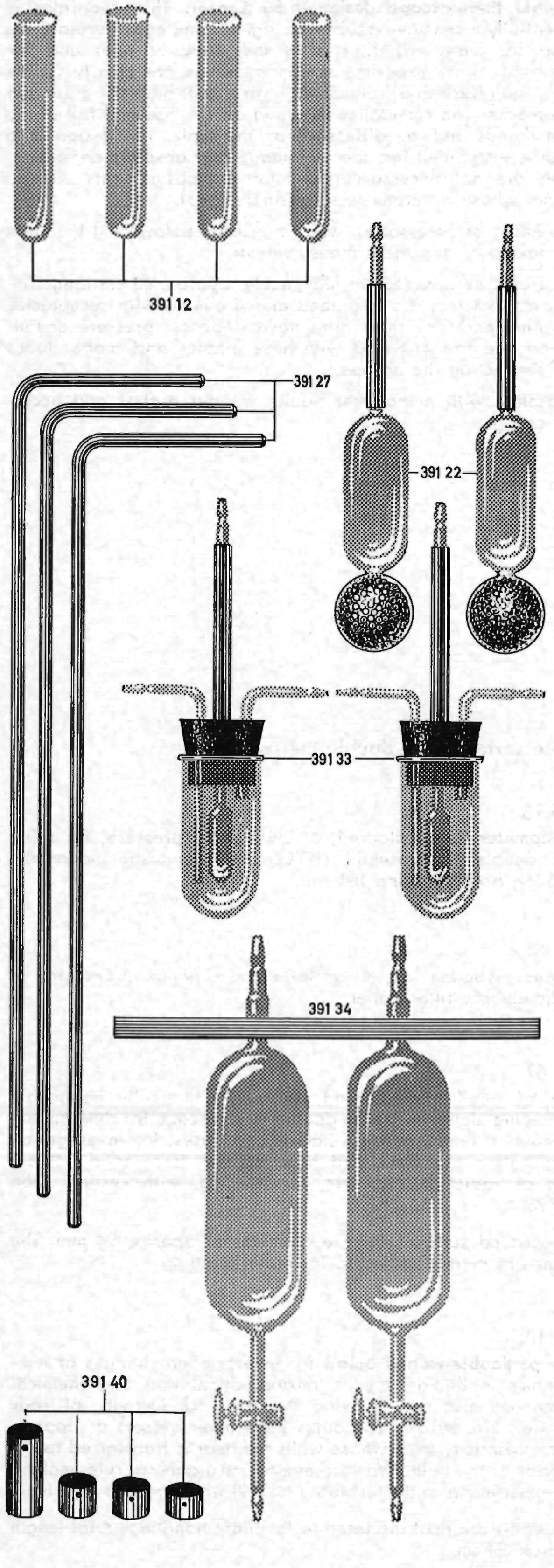
Pair of small plane-ground capsules, universally applicable measuring elements for the double thermoscope for determining changes of temperature in liquids and gases, for investigating evaporation processes and heat transfer from solid bodies; also as radiation receivers, for use e.g. with Leslie's cube (389 26).

The ground surfaces have a diameter of approx. 90 mm. The stems are heat-insulated to facilitate handling.

391 10

Pair of double-walled bulbs, for investigating changes of temperature in liquids, e.g. in mixing, dissolution and chemical reactions; also for studying the heat conductivity of rods (cf. Cat. No. 391 27). The bulbs have inner vessels of approx. 25 cm³ capacity from whose walls the heat is transferred to the interior of the bulb. We recommend, as a general rule, making the experiments in the test tubes (391 12) which are easy to clean.

The stems are heat-insulated to facilitate handling; total length approx. 24 cm.



391 12
Set of 4 test tubes for the double-walled bulbs (391 10).

391 22
Pair of glass sinkers, for determining the temperature of liquids, especially as a function of depth. The capsules are easy to sink into the liquid because they are weighted with a spherical attachment filled with lead shot. Overall length approx. 24 cm.

391 27
Set of 3 rods, for studying the heat conductivity of copper, iron and aluminium. The rectangularly bent rods are inserted into the double-walled bulbs by their short arms, and the long arms are heated with a burner. The double thermoscope will indicate the rise in temperature of the water in the capsules. Length, approx. 45 cm, dia. approx. 6 mm.

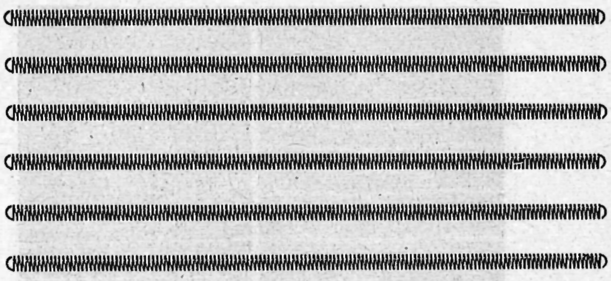
391 33
Pair of capsules for heat transfer. These capsules are arranged inside glass shells which are closed with cork stoppers. Through two of the three openings in the stopper gases or liquids can be introduced into the shell. The dependence of the heat transfer upon the kind of gas or liquid in the shell, which can be tested in a water bath, is clearly indicated.

391 34
Pair of capsules with shells that can be evacuated for investigating the dependence of heat transfer in gases upon pressure. The capsules are surrounded by glass shells ending in suction ports with stopcocks and hose nipples at the bottom, which can be evacuated with a vacuum pump.

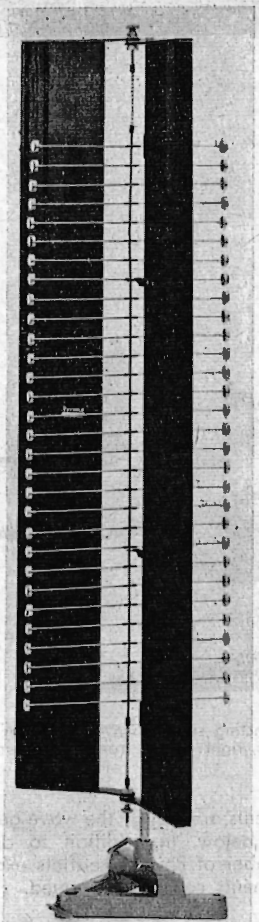
If the capsules are afterwards heated in a water bath, the heat transfer into the capsule can be observed and its dependence upon pressure can be measured.

Total length approx. 35 cm, mounted on a common holder.

391 40
Set of 4 metal objects for experiments on specific heat. Cylinders made of aluminium, steel, copper and lead, of equal mass (approx. 40 g), suspended on cords; these are brought to the same temperature in a water bath and their heat capacities are then compared with the double thermoscope by inserting them into the double-walled capsules; complete with cords.



401 01



401 10

401 01

Set of 6 long helical springs, for experiments on waves in a stretched string, e.g. progressive waves, fundamental and harmonic oscillations, plane and circularly polarised waves. Each spring is approx. 0.75 m long, has a diameter of 20 mm and is provided with hooks for attaching another spring at the ends.

See "LEYBOLD Physics Leaflets", DC 534.211; a, DC 534.221; a, DC 534.24; a, DC 534.27 a, DC 534.511.1; b.

401 10

Torsion apparatus for studying waves, for a convincing introduction to the study of waves, especially the origin and propagation of progressive waves, their reflection at a free or a fixed end, standing waves, fundamental and harmonic vibrations, behaviour of waves in homogeneous and discontinuous media.

The oscillating system of the apparatus is a vertically arranged torsion strip to which 30 horizontal torsional pendulums in the shape of a dumbbell are attached. Disturbances of one pendulum will be propagated along the entire system as torsional oscillations, and the ends of the pendulums, which are provided with white discs, will create the impression of a transverse wave. The speed of propagation of the waves can be increased by varying the moments of inertia of the individual pendulums. If the speed of propagation is only increased on one half of the length of the torsion strip, the behaviour of waves crossing the boundary between two media of different speeds of propagation can also be studied.

Overall height approx. 1 m, length of torsion strip approx. 80 cm, length of the pendulums approx. 15 cm. The torsion strip is suspended on ball chains which exert practically no restoring force. A locking device for the uppermost and the lowermost pendulum can be hooked in if desired. The tension of the strip is adjustable. The pendulums are arranged between two black hinged boards which are a protection in storage, help to bring the pendulums to rest between successive experiments and provide a contrasting background for the white faces of the pendulums.

Complete with stand rod and stand base.

The oscillations may be excited by hand, or by means of the standard electric motor. The generation of standing waves with the motor is shown in Fig. 30.

(Cf. LEYBOLD-Welle, No. 7).

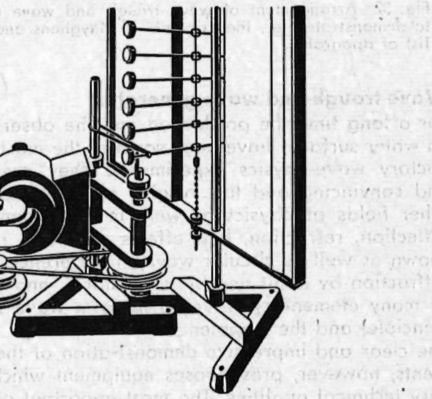


Fig. 30

Fig. 30

Exciting the torsion apparatus for studying waves (401 10) by means of the standard electric motor (347 25) with the eccentric attachment (347 28) clamped in its chuck. The eccentric attachment transfers low-amplitude oscillations to the lowest pendulum. The frequency range that can be so obtained contains all the harmonic oscillations of the torsion apparatus for studying waves.

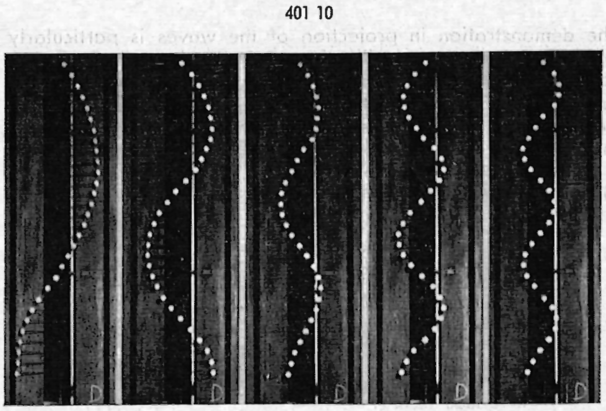
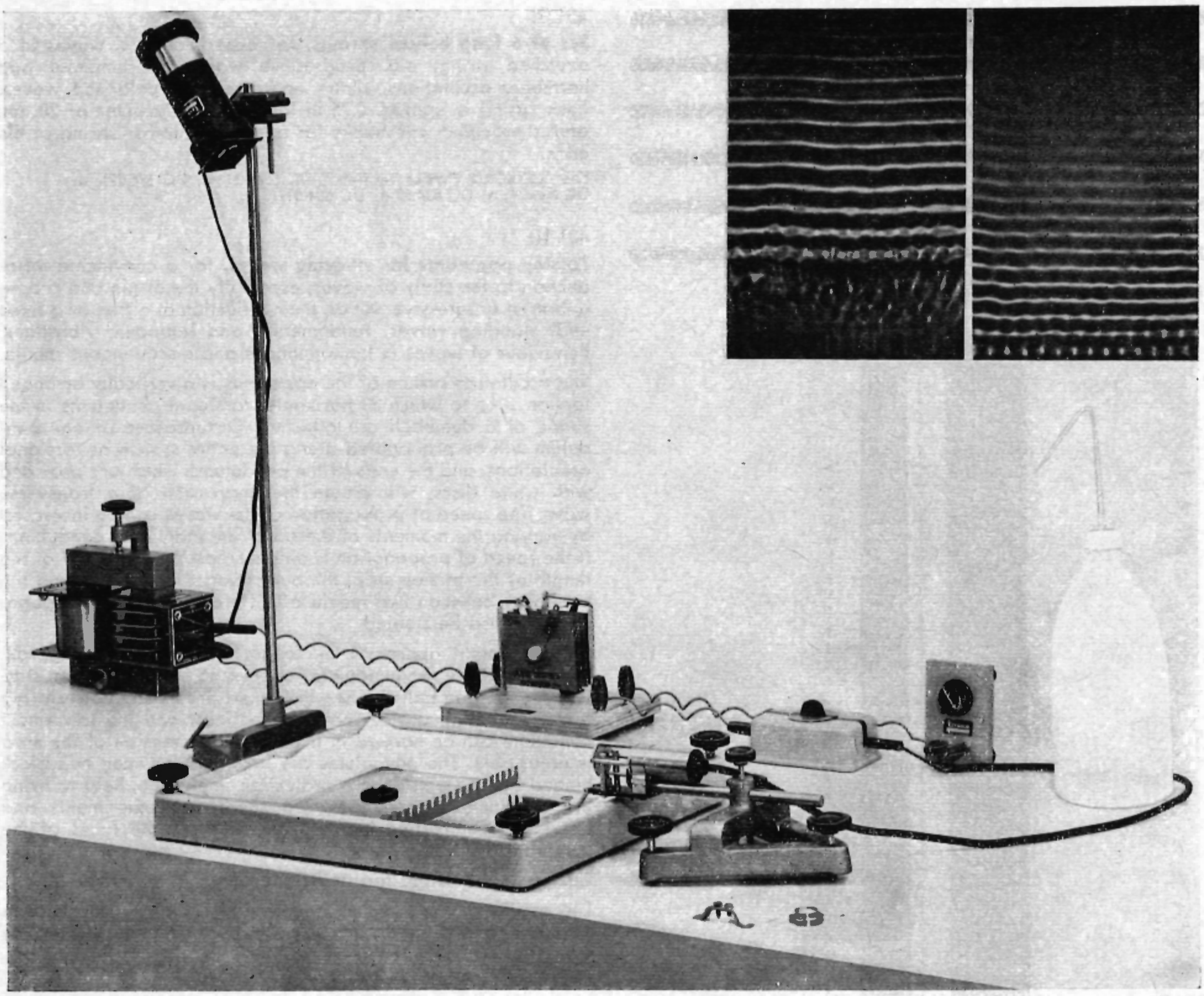


Fig. 31

PH 2023

Fig. 31

Standing waves generated by the torsion apparatus.



PH 2024

Fig. 32 Arrangement of wave trough and wave generator with illuminating device for projecting surface waves on water ("gravity ripples") to demonstrate e.g., the principle of Huyghens and Fresnel. Upper left: waves from many slits, right: waves from many sources. See below for list of apparatus.

Wave trough and wave generator

For a long time the production and the observation of ripples on water surfaces have been some of the most important introductory wave-physics experiments. They are comprehensible and convincing and the insights obtained can be applied to other fields of physics as well. In this manner plane waves, reflection, refraction, lens effects and total reflection can be shown as well as circular waves, interference, standing waves, diffraction by a slit and by an obstacle, and the superposition of many elementary wavelets to form wave fronts (Huyghens principle) and the Doppler effect.

The clear and impressive demonstration of these many experiments, however, presupposes equipment which has the necessary technical qualities. The most important of these are:

Rapid and exact adjustment of frequency, depth of immersion and amplitude of the wave generator, and a number of differently shaped generator attachments, to produce differently shaped wave fronts.

Sufficient size of the wave region, damping of reflections at the edges of the tank, good adjustment of the tank into a horizontal plane and easy checking of the depth of water. Further, adjustable stops, reflectors and glass plates for refraction, total reflection and lens effects.

Easily and quickly assembled and brilliant projection with point-shaped light source.

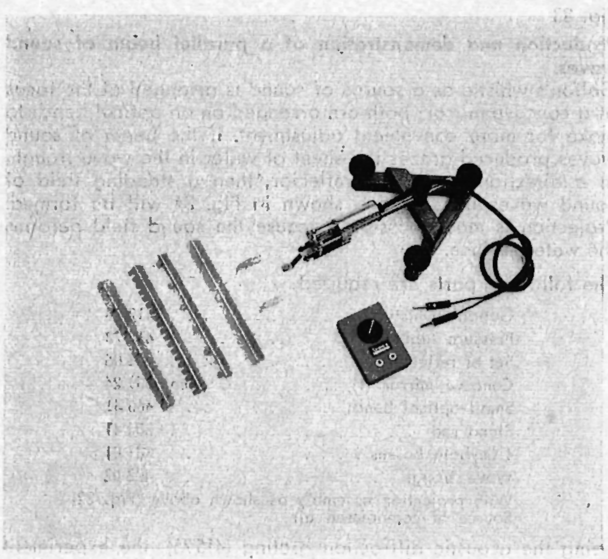
All these requirements are met by the wave generator and wave trough described below. In addition to detailed operating instructions, a number of Physics Leaflets explain how a large number of experiments can be performed.

(See "LEYBOLD Physics Leaflets", DC section 534 and Bulletin 29.)

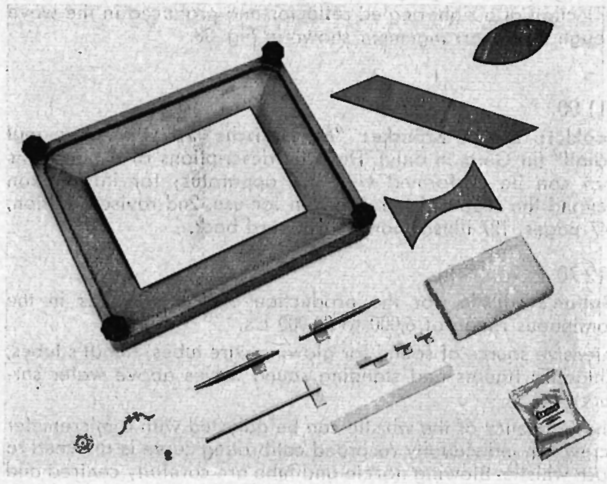
The demonstration in projection of the waves is particularly easy. The equipment is illuminated from above by a point-source of light; the image of the wave trains can then be seen on the ceiling in the light reflected by the mirror, or can be produced on a screen by the use of an obliquely arranged mirror.

The arrangement shown in Fig. 32 has been found very useful. It comprises:

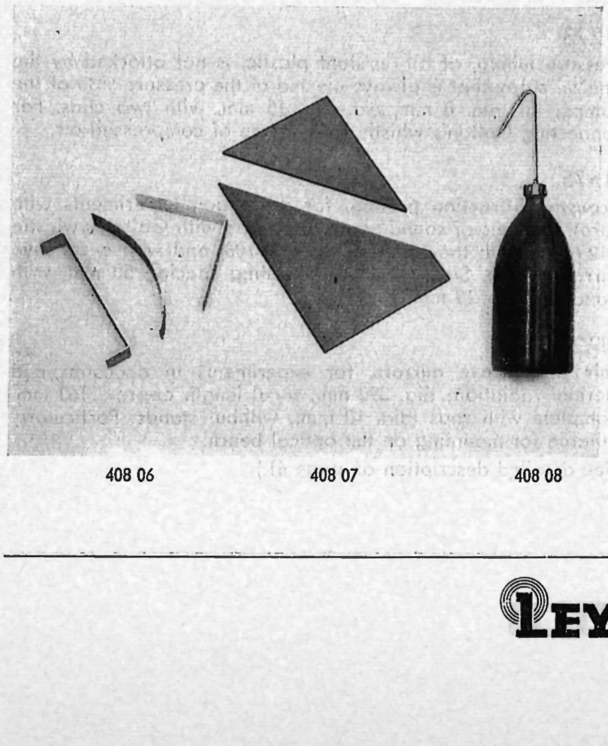
1 Wave generator	408 01
1 Wave trough	408 02
1 Lamp house	450 60
1 Lamp, 6 V, 30 W	450 51
1 Stand base	300 02
1 Leybold boss	301 01
1 Stand rod	300 43
1 Demountable transformer	562 11/12/14/18
1 Bridge rectifier	523 71
1 Cut-out switch	504 45



408 01



408 02



408 06 408 07 408 08

408 01

Wave generator, for continuous production of ripples in the wave trough.

Variable-speed D.C. motor for connection to 6–10 V, with gearing, eccentric attachment and rocker arm. The amplitude of the rocker arm to which the various attachments and stops are fitted can be adjusted by displacing the motor lengthwise in its holder. The motor is held by a stand rod which is clamped into a tripod with a lateral bore. With the help of three levelling screws the depth of immersion and the lateral inclination of the generator attachments can be adjusted very exactly.

The motor is supplied complete with the following accessories:

2 Attachments for generating circular waves
1 Attachment for generating plane waves
1 Attachment with 6 wave centres
1 Attachment with 19 wave centres
(can also be used as a stop with 18 slits)
1 Stop with 6 slits, acting as centres for 6 secondary wavelets.

Complete with tripod with 3 levelling screws, variable resistor on board with rotary knob, connecting cable and plugs.

Additionally required: a source of D.C., e.g. the low-tension power supply (522 38) or the demonstration transformer (562 11/12/14/18) with rectifier (523 71).

408 02

Wave trough, for demonstrating gravity ripples in projection, consisting of the following parts: Flat plastic trough with sloping side walls, approx. 47×37 cm², with 4 stainless levelling screws for horizontal adjustment, cloth to reduce reflection. Mirror, 31×21 cm², for projection with reflected light.

Set of plates of coloured glass, approx. 7 mm thick, in the shape of one converging lens, one diverging lens and one plano-parallel plate for refraction experiments.
Pair of variable stops;

Set of various screens for reflection and diffraction experiments;
Level, circular;

Depth gauge for adjusting the proper depth of water and wetting powder.

408 06

Set of reflectors for the wave trough, for demonstrating standing sound waves by deformation of the water surface in the wave trough.

The set consists of one plane, one spherical and one right-angled reflector, each of 5 cm height.

The arrangement for producing the sound waves with Galton's whistle and a concave mirror is shown in Fig. 33 and the projected image of a sound field is shown in Fig. 34.

408 07

Pair of right-angled glass triangles, for demonstrating total reflection and the occurence of the transversely damped penetration wave in the wave trough. If the second triangle is additionally used, the inhibition of total reflection occurs when the width of the barrier separating two areas of shallow water is small compared with the wavelength. This is a mechanical analogue to the effect of barrier penetration or tunnelling that occurs in the wave-mechanical treatment of elementary particles. The triangles will fit the wave trough.

408 08

Plastic bottle, capacity 2 litres, for easy control of the addition or subtraction of water when adjusting the depth of water in the wave trough.

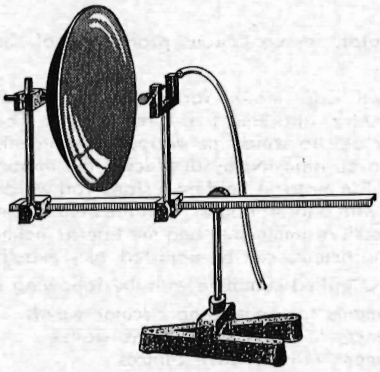


Fig. 33

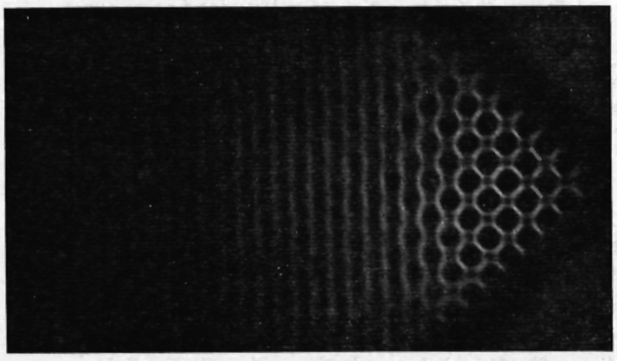
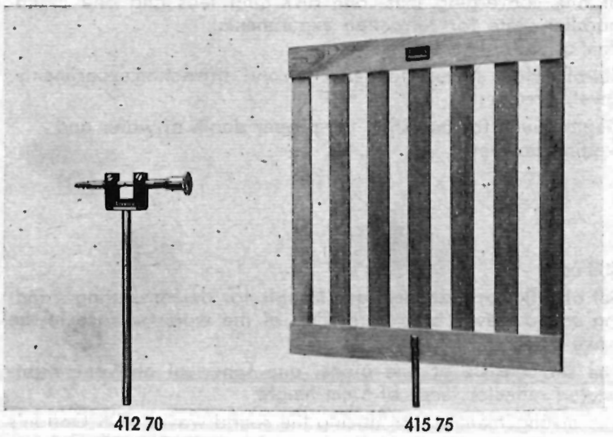
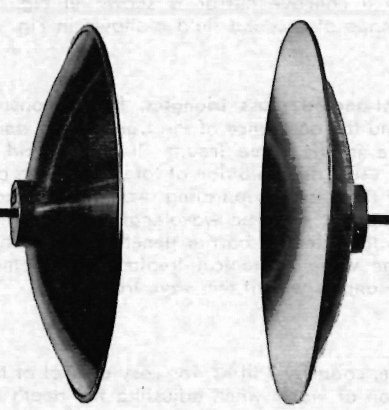


Fig. 34 PH 2025



412 70 415 75



389 24

Fig. 33

Production and demonstration of a parallel beam of sound waves.

Galton's whistle as a source of sound is arranged at the focus of a concave mirror; both are arranged on an optical bench to make for more convenient adjustment. If the beam of sound waves produced grazes the sheet of water in the wave trough, in a direction towards a reflector, then a standing field of sound waves like the one shown in Fig. 34 will be formed. Projection is made possible because the sound field deforms the water surface.

The following parts are required:

Galton's whistle	412 70
Pressure tubing	412 73
Set of reflectors	408 06
Concave mirror (1)	from 389 24
Small optical bench	460 41
Stand rod	300 41
4 Leybold bosses	301 01
Wave trough	408 02

With projection assembly as shown above (Fig. 32)
Source of compressed air

Using the acoustic diffraction grating (415 75), the experiment can be extended to the diffraction of sound waves.

Fig. 34

Photograph of the projected image of a sound field formed by reflection at a right-angled reflector and produced in the wave trough by the arrangement shown in Fig. 33.

411 00

Booklet: Dr. H. Kröncke: "Mechanische Schwingungen und Schall" (in German only). Detailed descriptions of experiments that can be performed with our apparatus; for information beyond the scope of the direction for use. 2nd revised edition, 147 pages, 127 illustrations, cardboard back.

412 70

Galton's whistle, for the production of sound waves in the continuous range of 6,000 to 30,000 c/s.

Intensive source of sound for glowing-wire tubes, Kundt's tubes, Chladni's figures and standing sound waves above water surfaces.

The frequency of the whistle can be adjusted with a micrometer screw. An individually recorded calibrating curve is attached to each whistle. Blowing nozzle and tube are carefully centred and arranged in a fork that is provided with a rod for mounting (dia. 10 mm).

Pressure required: 2 atmospheres absolute, can be produced with a vacuum pump D 2 (110 12 S or 110 13 S).

412 73

Pressure tubing, of oil-resistant plastic, is not attacked by the fine oil spray that is always ejected at the pressure side of the pumps; int. dia. 8 mm, ext. dia. 15 mm, with two clips. For connecting Galton's whistle to a source of compressed air.

415 75

Acoustic diffraction grating, for diffraction experiments with parallel beams of sound waves produced with Galton's whistle (412 70) or with the small speaker (580 06) and with a concave mirror (389 24). Size 40×40 cm², grating spacing 50 mm, with stand rod, dia. 12 mm.

389 24

Pair of concave mirrors, for experiments in acoustics and thermal radiation; dia. 390 mm, focal length approx. 160 mm. Complete with rods (dia. 10 mm), without stands. Particularly suitable for mounting on the optical bench.

(See detailed description on page 61.)

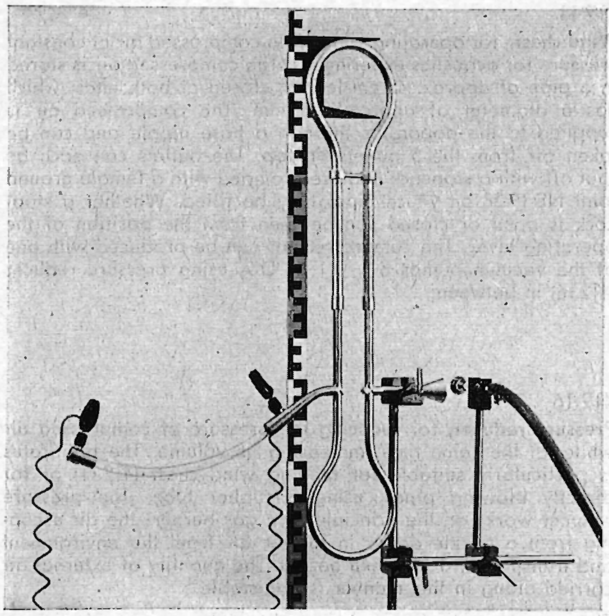
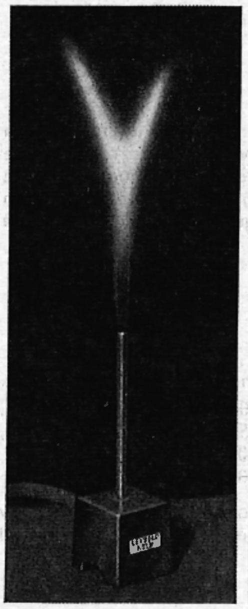
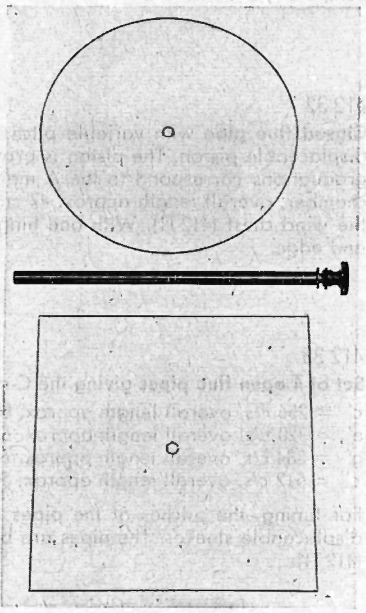


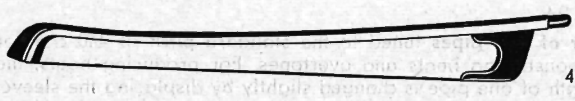
Fig. 35 PH 2038



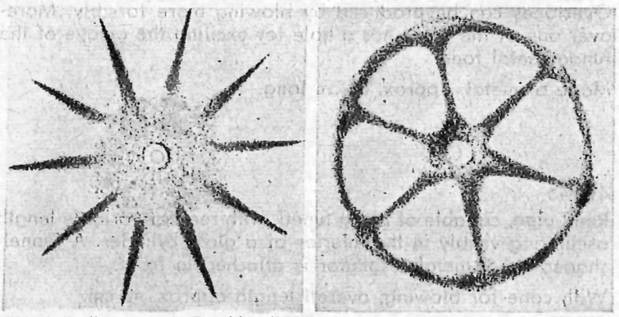
411 97
(Sensitive flame, blown at)



413 71



414 97



Chladni's figures, see Cat. No. 41371 PH 2026

413 51

Glowing wire tube, for a very impressive method of rendering standing sound waves of short wavelength visible: the apparatus works similarly to Kundt's tube, but the indicator used here is a filament glowing at dull red heat which cools off at the antinodes of the standing wave, the glowing wire thus indicating the nodes and antinodes of the wave by alternating bright and dark parts.

Glass tube, approx. 25 cm long, bent, with metal caps between which the filament is stretched, and terminals for making electrical connections. One end is constructed to fit onto the interference tube.

Voltage required: approx. 30 V. Complete with spare wire; without resistor and stand.

For assembly we recommend the following parts (cf. Fig. 35):

1 Glowing wire tube	413 51
1 Galton's whistle as source of sound	412 70
1 Length of pressure tubing	412 73
1 Interference tube for measuring the wavelength	415 05
As source of voltage, for example:	
Demountable transformer, consisting of:	
1 U-core with yoke and clamping device	562 11/12
1 Coil with 1,000 turns (at 220 V mains voltage)	562 15
or	
1 Coil with 500 turns (at 110 V mains voltage)	562 14
1 Coil with 250 turns	562 13
1 Series resistor, 110 Ω	537 24
1 Vertical scale	311 22
Stands, connecting leads	

413 54

Spare wire for the glowing-wire tube (one length included with 41351).

415 05

Interference tube, for measuring the wavelength of sound waves with the glowing wire tube (41351) as an indicator. We recommend using Galton's whistle (41270) as source of sound.

Made of metal, nickel-plated, with one short, stationary, and one long, telescopic arm. Total height: max. 65 cm; suitable for fitting to the glowing wire tube; without stand.

411 97

Burner for sensitive flames. The gas supply can be so regulated as to produce a high, quietly burning flame. This flame reacts very sensitively to sound waves: the streamline state changes abruptly to the turbulent state if exposed to sound waves, and the flame sinks to less than half its original height. With heavy base; only suitable for coal gas.

413 71

Pair of Chladni's plates, for producing Chladni's figures. These should be strewn with fine, dry sand and then either stroked with bass bow (41497) or blown at with Galton's whistle. The small speaker (58006) operated from RC-oscillator (58700) is also extremely suitable for excitation. In the resonance case the sand will arrange itself in a characteristic vibration pattern which can also be projected.

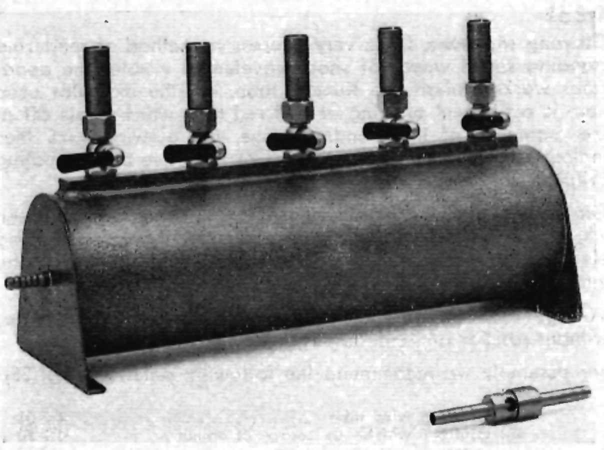
The apparatus consists of:

Square plate of glass, 20×20 cm², with hole
Round plate of glass, dia. 200 mm, with hole
Holder with rod, dia. 10 mm

We recommend using bench clamp (30106) for clamping the holder.

414 97

Bass bow, for stroking plates and strings; 75 cm long.



412 11
412 16

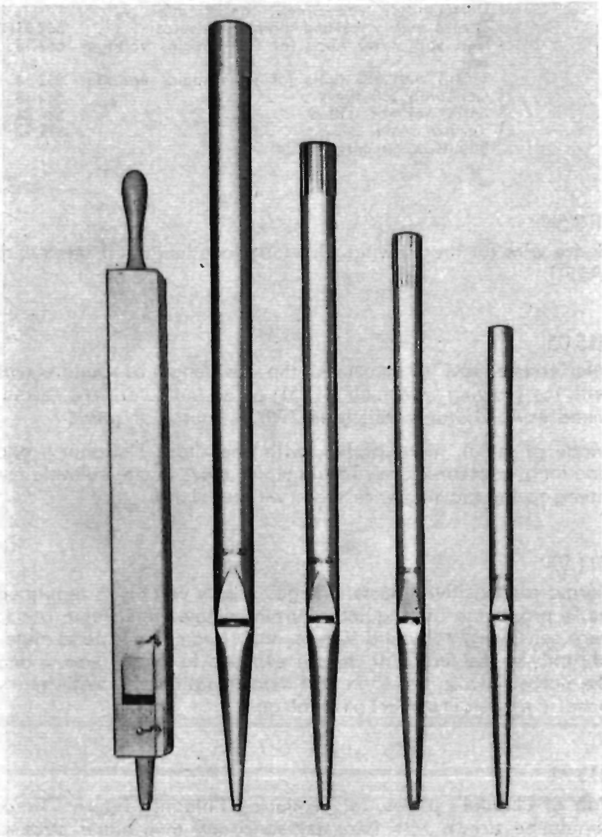
412 11

Wind chest, for operating pipes with compressed air at constant pressure for acoustics experiments. The compressed air is stored in a pipe of approx. 45 cm length, closed at both ends, which has a diameter of approx. 130 mm. The compressed air is supplied to the apparatus through a hose nipple and can be taken off from the 5 outlets on top. The outlets can each be shut off with a stopcock and are provided with a female ground joint NS 19/38 on which pipes may be fitted. Whether a stopcock is open or closed can be seen from the position of the operating lever. The compressed air can be produced with one of the vacuum pumps S 1, D 1 or D 2, using pressure reducer (412 16) in between.

412 16

Pressure reducer, for reducing the pressure of compressed air while, at the same time, increasing its volume. The apparatus is particularly suitable for feeding wind chest (412 11) or for directly blowing pipes, using a rubber tube. The pressure reducer works on the principle of a gas burner: the air escaping from a nozzle draws in further air from the environment and transports it to the exit nozzle. The quantity of external air carried along in this manner is adjustable.

The compressed air can be produced by means of vacuum pumps S 1, D 1 and D 2.



412 32
412 33

412 32

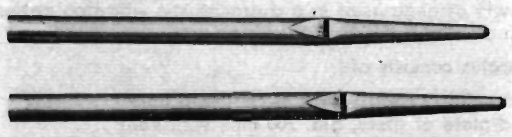
Closed flue pipe with variable pitch. This pipe is closed by a displaceable piston. The piston is provided with a scale whose graduations correspond to the A major scale. Square wooden chamber, overall length approx. 47 cm, with cone for fitting on the wind chest (412 11). With one hinged side wall to show slit and edge.

412 33

Set of 4 open flue pipes giving the C-major chord, consisting of:

c' = 256 c/s, overall length approx. 80 cm; dia. approx. 40 mm,
e' = 320 c/s, overall length approx. 65 cm; dia. approx. 35 mm,
g' = 384 c/s, overall length approx. 60 cm; dia. approx. 30 mm,
c'' = 512 c/s, overall length approx. 50 cm; dia. approx. 25 mm.

For tuning, the pitches of the pipes can be varied slightly by displaceable sleeves. The pipes are best blown with wind chest (412 11).

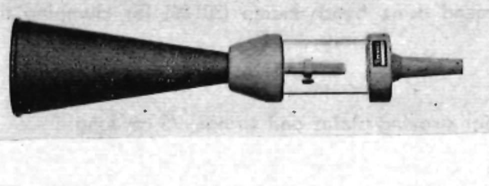


412 34

412 34

Pair of flue pipes tuned to the standard pitch of 440 c/s; for demonstrating beats and overtones. For producing beats, the length of one pipe is changed slightly by displacing the sleeve. Overtones can be produced by blowing more forcibly. Moreover one of the pipes has a hole for exciting the octave of the fundamental tone.

Made of metal, approx. 50 cm long.

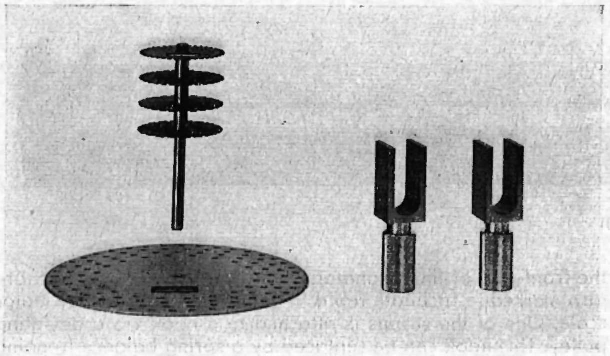


412 45

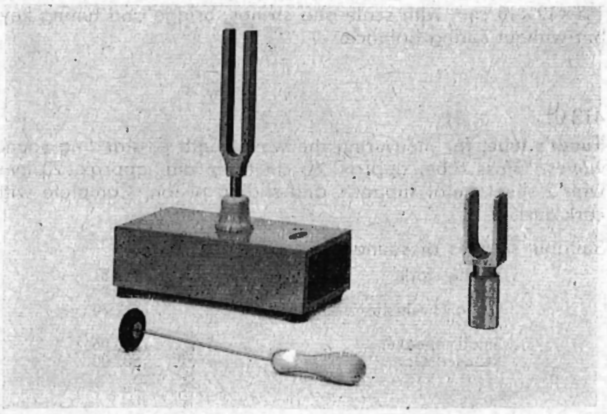
412 45

Reed pipe, capable of being tuned, with reed of variable length oscillating visibly in the interior of a glass cylinder. A funnel-shaped sheet metal resonator is attached in front.

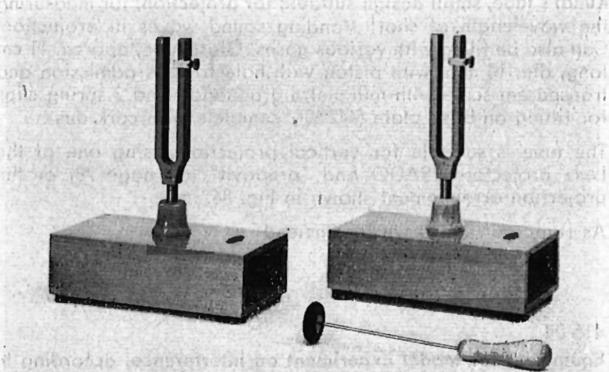
With cone for blowing, overall length approx. 40 cm.



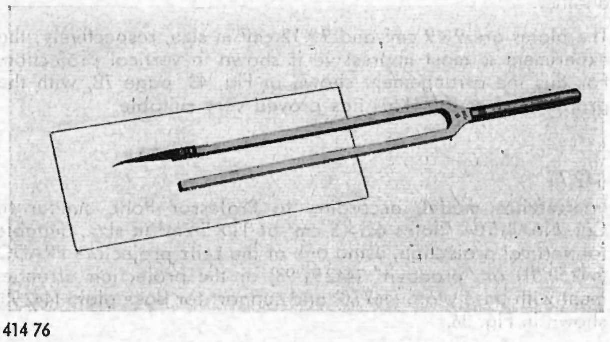
347 74
347 73
411 83



414 42
411 81



414 72



414 76

347 73

Disc siren, metal disc, dia. approx. 200 mm, with 4 rows of equidistant holes. When all the rows of the rotating disc are simultaneously blown with a blower a major chord will be obtained. For use on the hand rotator (347 15) or the standard electric motor (347 25/26). Must be mounted on disc holder (347 13).

347 74

Savart's wheels. Four metal discs (dia. approx. 70 mm) with differently spaced teeth are arranged one above the other a short distance apart on a common axle. When these are set in revolution and the edges are simultaneously touched with a sheet of cardboard or plastic, a major chord will be obtained. For use on the hand rotator (347 15) or standard electric motor (347 25/26).

411 81

Tuning fork, made of light metal, 1,700 c/s; very robust tuning fork which can be struck strongly and forms a very intensive source of sound. With this tuning fork dust figures in Kundt's tube (413 01) are very simple to produce.
Overall length approx. 10 cm.

411 83

Pair of tuning forks, made of light metal. Two forks 411 81 tuned to the same frequency. In order to produce beats the two tuning forks can be brought out of tune by warming one of them.

414 42

Tuning fork, 440 c/s, for producing the standard pitch; can also be used to measure the frequency of the rotary mirror when determining the speed of light. On resonance box, approx. 18×9×5 cm^3 in size, complete with hammer.

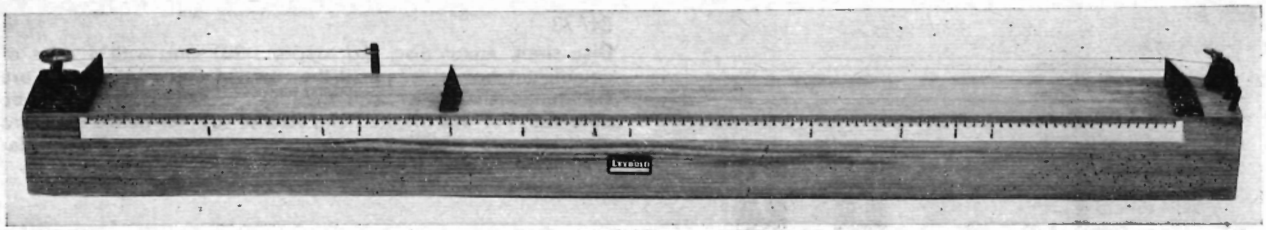
414 72

Pair of resonance tuning forks, 440 c/s, 2 tuning forks (414 42); complete with hammer and displaceable tuning weights for experiments on beats.

414 76

Recording tuning fork, 128 c/s; the long prongs can be made to oscillate with large amplitude if the fork is struck lightly. A pointed metal pen attached to one of the two prongs will trace a damped sine curve if passed across a glass plate covered with soot at an even speed.

Overall length of tuning fork: approx. 28 cm; complete with glass plate.

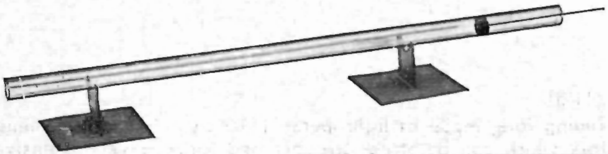


414 01

414 01

Monochord (sonometer), for experiments with vibrating strings. The strings are mounted on a wooden box resonator and can be tensioned by means of pegs. The useful length of the strings is 120 cm.

The pitch can be varied by changing the tension of a string, or by displacing the bridge to vary the length of a string. The position of the bridge can be read on the millimetre scale on the front side of the resonator. The ratios 1/6, 1/5, 1/4, 1/3, etc. are also marked to facilitate rapid finding of the notes of the major scale. One of the strings is attached to a hook via a deviating pulley. This hook can be replaced by a spring balance [reading up to 10 kp (kg wt), 314 20]. With the use of the spring balance the dependence of pitch upon the tension of the string can be determined. Complete with wooden box resonator, approx. 135×12×10 cm^3, with scale and strings, bridge and tuning key, but without spring balance.



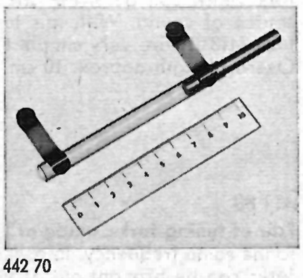
413 01

413 01

Kundt's tube, for measuring the wavelength of standing sound waves. Glass tube, approx. 60 cm long, dia. approx. 20 mm, with 2 sheet-metal supports and sliding piston. Complete with cork dust.

Suitable sources of sound:

Tuning fork	411 81
or	
Galton's whistle	412 70
or	
Small speaker	580 06
RC-oscillator	587 00



442 70

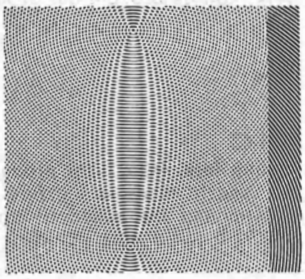
442 70

Kundt's tube, small design suitable for projection, for measuring the wavelength of short standing sound waves in projection. Can also be filled with various gases. Glass tube, approx. 11 cm long, dia. 10 mm, with piston with hole for gas admission and transparent scale with millimetre graduation and 2 spring clips for fitting on base plate (442 60); complete with cork dust.

The tube is suitable for vertical projection, using one of the Leitz projectors PRADO and "pradovit" (cf. page 78) or the projection arrangement shown in Fig. 36.

As source of sound we recommend:

1 Galton's whistle	412 70

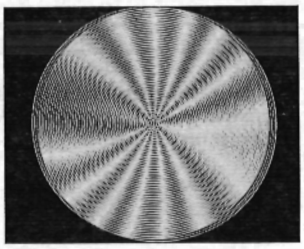


415 04 (projected image)

415 04

Equipment for model experiment on interference, according to Professor Pohl, consisting of two transparent plastic plates with printed concentric systems of rings. If laid on top of one another, the plates explain the origin of interference when the centres of the two systems are displaced relative to one another.

The plates are 9×9 cm^2 and 9×12 cm^2 in size, respectively; the experiment is most impressive if shown in vertical projection. For this the arrangement shown in Fig. 43, page 78, with the projection frame (441 51) has proved very suitable.



442 71 (projected image)

442 71

Interference model, according to Professor Pohl, similar to Cat. No. 415 04. Plates 6.5×5 cm^2 or 11×5 cm^2 in size. Suitable for vertical projection, using one of the Leitz projectors PRADO (442 50/51) or "pradovit" (442 91/93) or the projection arrangement with base plate (442 60) and support for base plate (442 90) shown in Fig. 36.

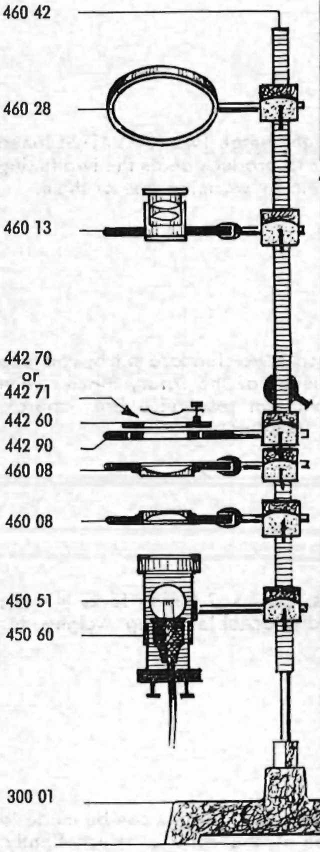
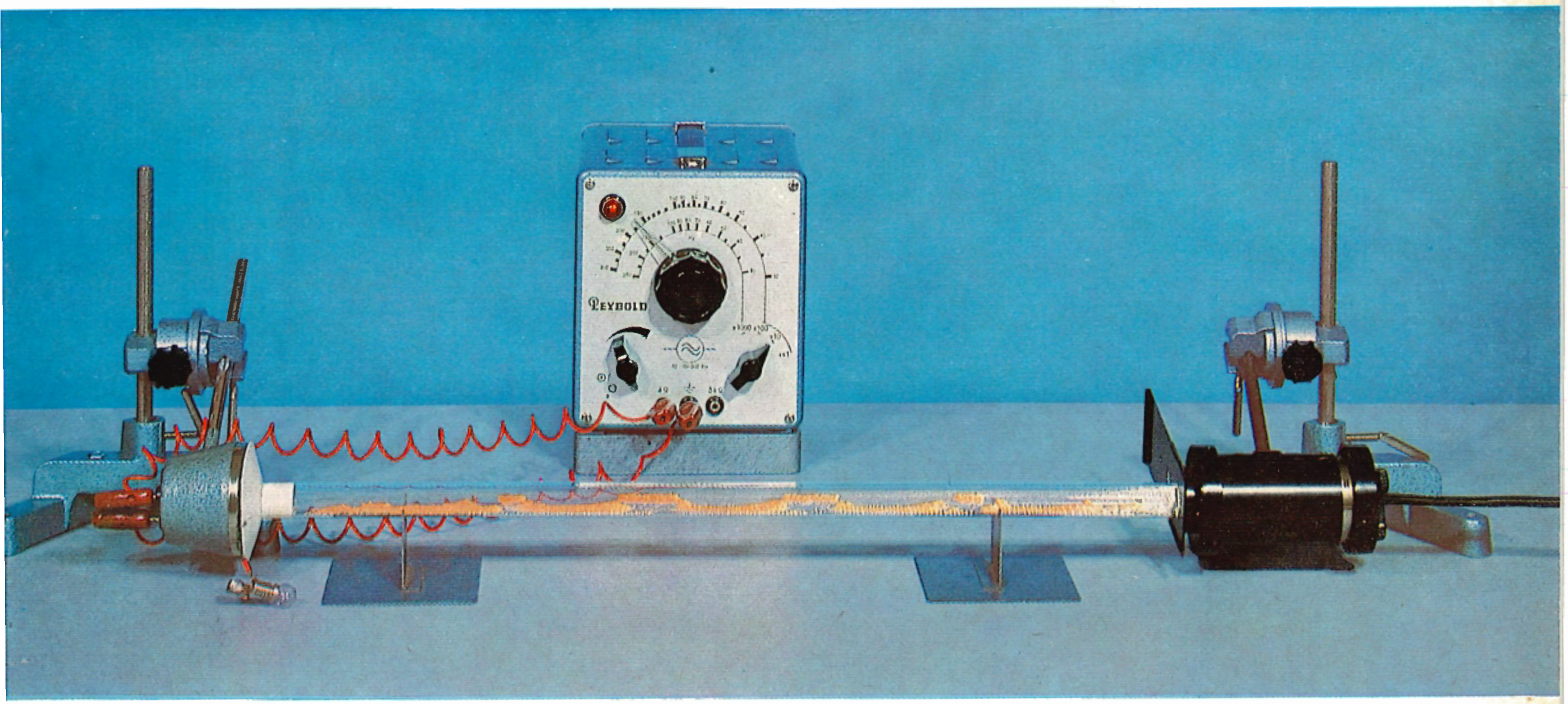


Fig. 36
Projection arrangement assembled from single parts. All the experiments that are possible with the accessories to the Leitz projectors PRADO and "pradovit" (cf. pages 101 to 105) can be demonstrated with this arrangement as well.
A similar projection arrangement, which is, however, only suitable for particular items of LEYBOLD apparatus, is described on p. 78.



A small speaker and the RC-oscillator are used to excite longitudinal oscillations in an air column in Kundt's tube. The standing waves are rendered visible by means of cork dust.

PLATE IV

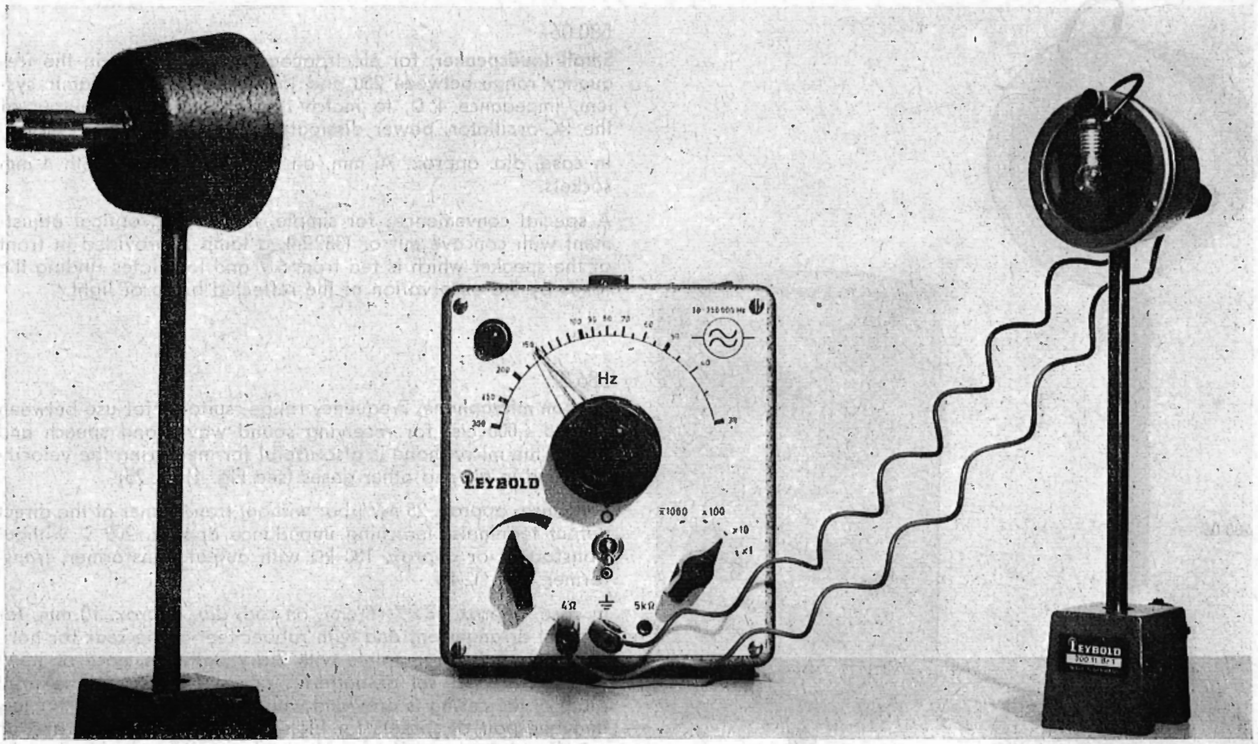
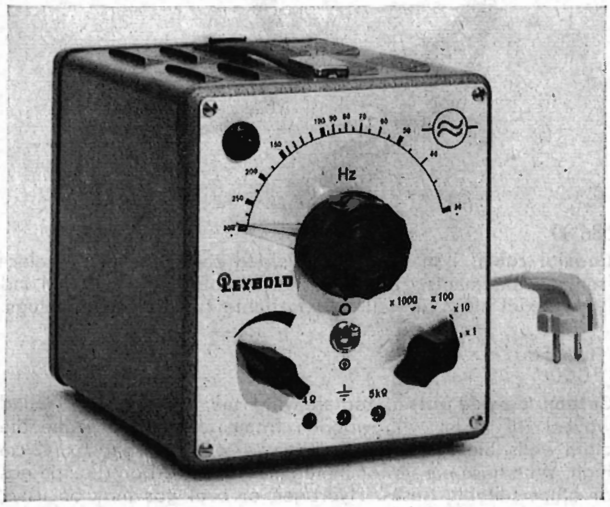


Fig. 37 Acoustics with electronic apparatus. RC-oscillator (587 00) with small speaker (580 06) and crystal microphone (586 29). PH 2027

Acoustics with electronic apparatus

Frequently acoustics experiments are only performed with the standard mechanical apparatus. The sources of sound then used are pipes, strings and tuning forks, and the sound detectors are the human ear, sensitive flames, radiometers or, as described above, a water surface. Recently electroacoustic means have become available for the performance of these experiments which simplify, in many cases, the experimental technique and permit a number of additional acoustics experiments to be done. The source of sound used in this case is a loud-speaker that transforms the electric oscillations of an electronic oscillator into sound waves. Such a speaker is for all practical purposes a point source and has a very constant frequency and intensity. The detector used is a microphone which gives out electric impulses which can be amplified and shown on an electric meter or an oscilloscope. We consider electroacoustic apparatus an excellent addition to the standard mechanical means, for in the age of wireless and television the use of electroacoustic apparatus also links up with the daily experience of the pupil. Experiments with the equipment described below were discussed in detail in the quarterly LEYBOLD house-magazine, No's 5–6.



587 00

587 00

RC-Oscillator, frequency generator for sinusoidal pulses, frequency range between 30 c/s to 300 kc/s. For producing sound waves the alternating voltages produced by the oscillator must be transformed into sound waves by means of a loud-speaker. If the small speaker is used, this gives the point source of sound of highly constant frequency and amplitude required in so many experiments (see p. 75 for examples).

Details about the use of the RC-oscillator in electricity will be found on p. 162.

Technical data:

Frequency continuously variable in 4 (switched) ranges, viz. 30 c/s – 300 kc/s.

The amplitude is stabilised, frequency-independent and variable. Maximum voltage at the low-impedance output under normal operating conditions: 75 V peak to peak.

Outputs:

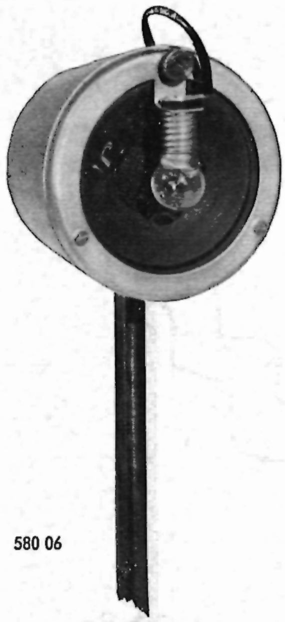
1. Low-impedance output through a transformer, matching resistance 4 Ω
2. High-impedance output, matching resistance 5 kΩ

Power-output: 2.5–3 W

With printed circuit

Tube complement: 1 Double triode ECC 81
1 Triode-pentode ECC 82
1 Thermistor stabilizer

Supplied for connection to 110, 130, 150, 220 and 240 V. In metal case, approx. 17×22×20 cm³, with carrier handle and mains cable.



580 06

580 06

Small loudspeaker, for electroacoustic experiments in the frequency range between 250 and 15,000 c/s. Electrodynamic system, impedance 4 Ω, to match the low-impedance output of the RC-oscillator, power dissipation approx. 1 W.

In case, dia. approx. 70 mm, on rod, dia. 10 mm, with 4 mm sockets.

A special convenience: for simple, time-saving optical adjustment with concave mirror (389 24), a lamp is provided in front of the speaker which is fed from 6 V and facilitates finding the focus by the observation of the reflected beam of light.

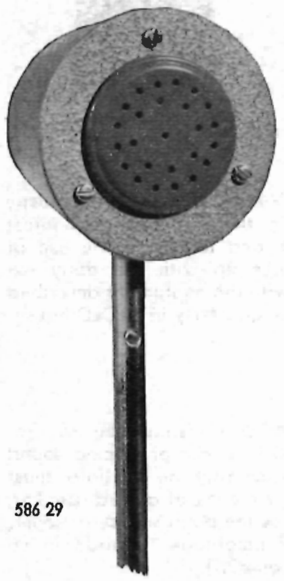
586 27

586 27

Carbon microphone. Frequency range: suitable for use between 50 and 4,000 c/s; for receiving sound waves and speech and music; the microphone is also useful for measuring the velocity of sound in air and other gases (see Fig. 41, p. 75).

Response: approx. 25 mV/μbar without transformer at the direct output terminals; matching impedance approx. 200 Ω without transformer or approx. 100 kΩ with output transformer, transformer ratio 1:4.4.

In case, approx. 13×7×5 cm³, on rod, dia. approx. 10 mm, for vertical arrangement and with rubber feet at the rear for horizontal operation, complete with 2 dry batteries, each of 1.5 V, working life per set of batteries approx. 25 hours. The front plate of the casing is provided with one pair of sockets for low and one pair of sockets for high matching impedance and an on-off switch. A small lamp at the front indicates whether the microphone is switched on and ready for use.

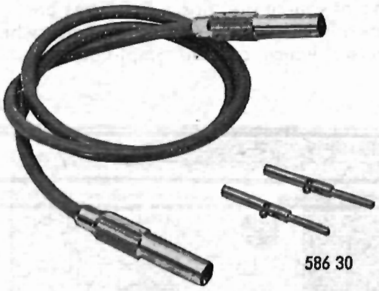


586 29

586 29

Crystal microphone, high impedance, frequency range 50 c/s to 15 kc/s; particularly suitable for experiments with the directional sound receiver (see Fig. 38, p. 75) and for receiving speech and music. Resonance peaks do not occur below 5 kc/s. Response: approx. 5.5 mV/μbar.

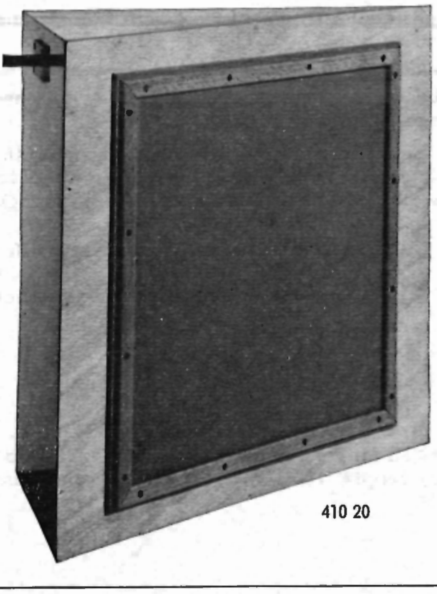
In conical case, dia. 70 mm, on rod, dia. 10 mm. With one socket for connecting the coaxial cable (586 30) or a 4 mm plug, and with one earthing socket.



586 30

586 30

Coaxial cable, 1 m long; as shielded cable for use in electronics experiments. Highly insulated cable with shielding and two coaxial plugs as well as detachable 4 mm extension plugs.



410 20

410 20

Carbon dioxide prism, for showing the refraction of sound waves; 30° prism with wooden frame and sound-permeable cloth walls. Sides approx. 23, 40 and 47 cm long, approx. 42 cm high. With hose nipple for the admission of carbon dioxide gas or other suitable gases. Hydrogen or coal gas may be used, but are explosive.

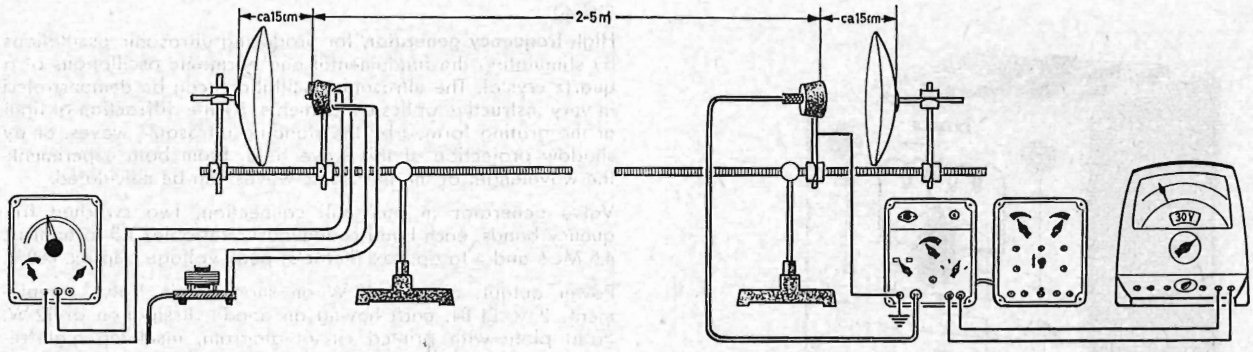


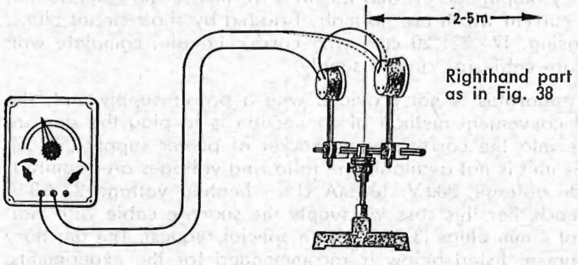
Fig. 38

Directional source of sound and directional receiver, for studying sound propagation, reflection, absorption and, with the use of a little additional apparatus, for producing standing waves, refraction and diffraction.

The source of sound is a small speaker arranged at the focus of a concave mirror on the optical bench. This arrangement can also be set up on a rotatable disc. The speaker is operated by means of the RC-oscillator. The receiver is arranged correspondingly: the microphone is at the focus of the second concave mirror. The pulses received are amplified and fed to the demonstration multirange meter or to an oscilloscope.

Apparatus required:

1 RC-oscillator	587 00
1 Amplifier	580 00
1 Power supply	522 35
1 Demonstration multirange meter	531 86
or	
1 School cathode ray oscilloscope	575 15
1 Small speaker	580 06
1 Crystal microphone	586 29
1 Coaxial cable	586 30
2 Optical benches	460 41
1 Pair of concave mirrors	389 24
1 Transformer	562 76
Stands	
For refraction experiments, in addition:	
1 Carbon dioxide prism	410 20
For diffraction experiments:	
1 Acoustic diffraction grating	415 75
For standing waves, reflection, diffraction and interference	
2 Reflector plates	582 33



Righthand part
as in Fig. 38

Fig. 39

Interference of sound waves

Two speakers operated from a common RC-oscillator in phase or in antiphase are used. The receiver is the same as in the previous experiment. This arrangement can be used to detect the maxima and minima of the sound field in front of the two speakers. Apparatus required: as in Fig. 38.
In addition, 1 more small speaker (580 06)

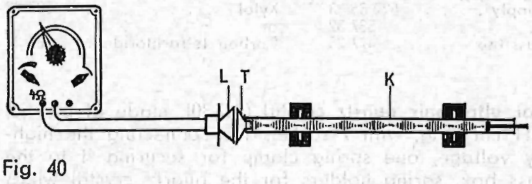


Fig. 40

Frequency determinations with Kundt's dust figures

The frequency of sound waves can be calculated from the wavelength of the standing sound waves in Kundt's tube. The experiment can be used to check the frequency scale of the RC-oscillator. The speaker is arranged in front of Kundt's tube, which should be provided with a matching funnel made of cardboard to match its sound impedance to that of the tube. Chladni's plates (413 71) can be set in vibration in the same manner.

Apparatus required:

1 RC-oscillator	587 00
1 Small speaker	580 06
1 Kundt's tube	413 01
or	
1 Pair of Chladni's plates	413 71

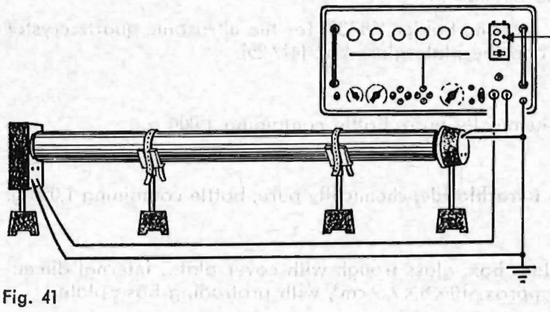


Fig. 41

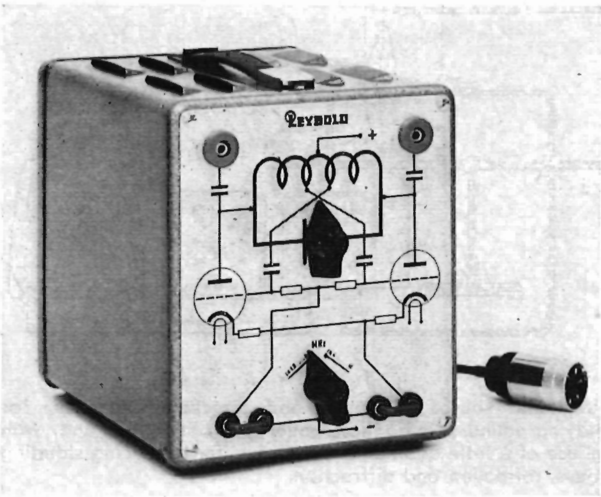
Fig. 41

Measurement of the velocity of sound in gases, using the demonstration scaler and the flip-flop unit for starting and stopping the scaler.

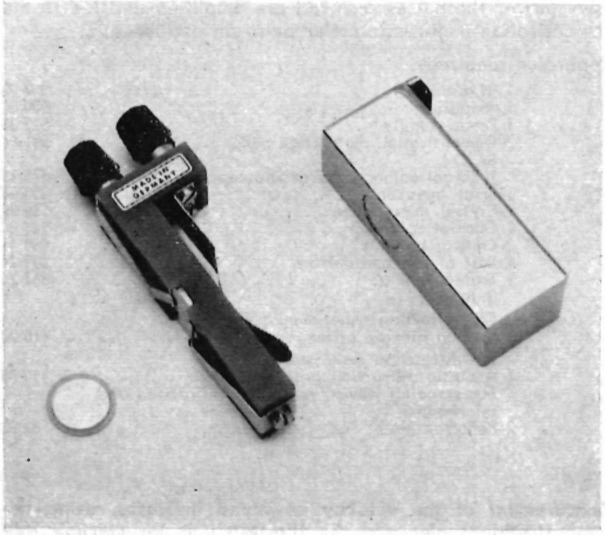
In this experiment the time-base generally used is the quartz-stabilised oscillation of the 10 kc/s frequency generator unit inside the demonstration scaler; but the RC-oscillator may also be used. By means of the start button on the plug-in flip-flop unit an electric pulse is formed which produces a sound pulse in the speaker and simultaneously starts the scaler. While the scaler is running, the oscillations produced by the frequency generator are counted by the scaler. After a certain transit time the sound pulse reaches the microphone and is transformed back into an electric pulse that terminates the scaling process. The transit time of the sound pulse can then be read from the number of recorded oscillations. The accuracy is sufficient to demonstrate the dependence of the velocity of sound on temperature and on the kind of gas used.

Apparatus required:

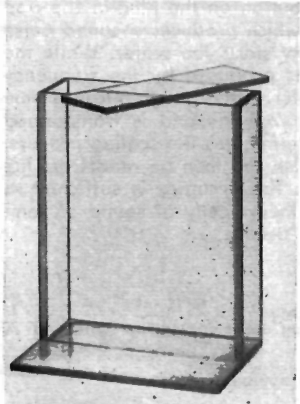
1 Demonstration scaler	559 62
1 10 kc/s frequency generator unit	559 73
1 Flip-flop unit for starting and stopping the scaler	559 70
1 Small speaker	580 06
1 Carbon microphone	586 27
1 Cardboard tube, length approx. 1 m, dia. approx. 65 mm	
2 Tube clamps	301 71
4 Saddle bases	300 11



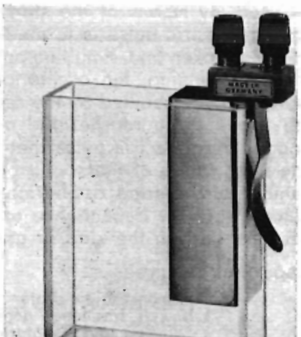
587 40



587 30 587 32 587 34



477 25



477 25, 587 32, 587 34

587 40

High-frequency generator, for producing ultrasonic oscillations by stimulating the fundamental and harmonic oscillations of a quartz crystal. The ultrasonic oscillations can be demonstrated in very instructive optics experiments: by the diffraction of light at the grating formed by the standing ultrasonic waves, or by shadow projection of this wave field. From both experiments the wavelength of the ultrasonic waves can be calculated.

Valve generator in push-pull connection, two switched frequency bands, each band continuously variable: 1.5 to approx. 4.5 Mc/s and 4 to approx. 10 Mc/s; peak voltage approx. 400 V.

Power output: approx. 10 W on short-circuit. Valve complement: 2 × EL 84, each having an anode dissipation of 12 W. Front plate with printed circuit diagram, insulated high-frequency output sockets and facilities for measuring cathode and grid current which are normally bridged by short-circuit plugs. In casing, 17×22×20 cm³, with carrier handle, complete with six-core cable for current supply.

The apparatus is not provided with a power supply unit; the most convenient method of connection is to plug the six-core cable into the corresponding socket of power supply (522 35). If this unit is not available the following voltages are required: anode voltage, 300 V, 100 mA D.C.; heating voltage 2×6.3 V, 1 A each. For this case we supply the six-core cable with individual 4 mm plugs (310 03 106) on special request. The ancillary equipment listed below is recommended for the experiments.

587 30

Ultrasonic quartz crystal, for the production of ultrasonic oscillations, to be stimulated by the high-frequency generator; dia. approx. 20 mm, approx. 1.5 mm thick; natural frequency: approx. 2 Mc/s, with silver-coated surfaces that serve as electrodes for applying the high-frequency voltage.

For operation we recommend:

1 High-frequency generator	587 40	1 Metal box	587 34
1 Power supply	522 35/33	Xylol	587 33
1 Holder	587 32	or	
1 Plate glass box	477 25	Carbon tetrachloride	587 35

587 32

Holder for ultrasonic quartz crystal (587 30), made of plastic, approx. 11 cm long, with 2 sockets for connecting the high-frequency voltage, one spring clamp for securing it to the plate glass box, spring holders for the quartz crystal which also supply the high-frequency voltage to it.

The device is designed for insertion into a plate glass box. When this is filled with xylol or carbon tetrachloride, standing ultrasonic waves can be produced, which can be demonstrated by light diffraction or by shadow projection.

We recommend using plate glass box 477 25.

587 34

Metal box, for producing standing ultrasonic waves in electrically conductive fluids. Box, approx. 2.5×3×8 cm³ in size, with a metal window on the front that is closed with a thin copper membrane. Ultrasonic waves produced inside the box in a non-conductive liquid can penetrate through the copper membrane and can then be demonstrated in a conductive liquid provided outside it.

For use with the holder (587 32) for the ultrasonic quartz crystal (587 30) and the plate glass box (477 25).

587 33

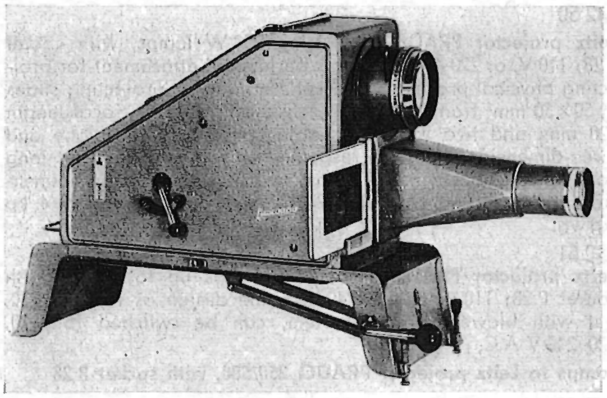
Xylol, chemically pure, bottle containing 1,000 g.

587 35

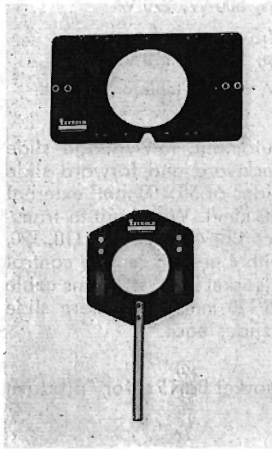
Carbon tetrachloride, chemically pure, bottle containing 1,000 g.

477 25

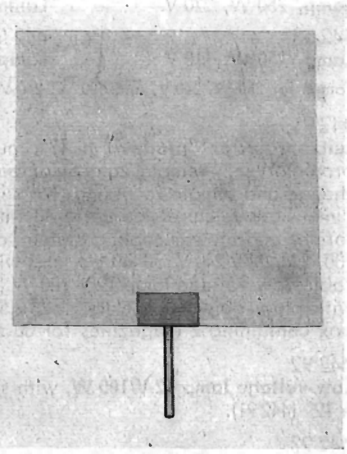
Plate glass box, glass trough with cover plate; internal dimensions: approx. 10×8×2.5 cm³, with protruding base plate.



441 32



441 51
442 90



441 53

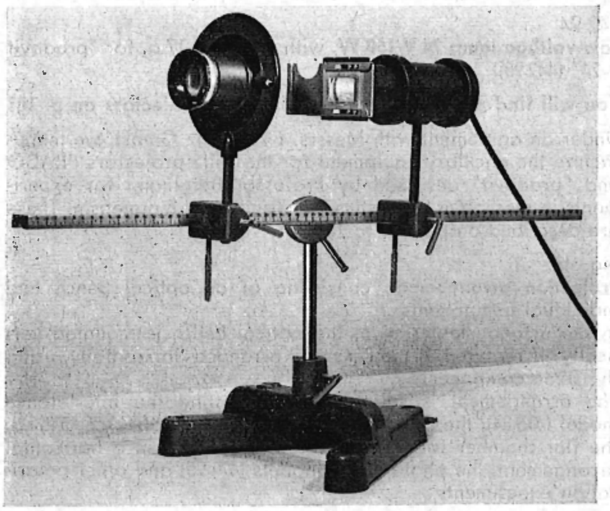


Fig. 42 PH 2028

Projection device, assembled from individual components for projecting 24×36 mm² slides in 50×50 mm² frames. The dual gauge mavometer (442 73) can also be projected by this arrangement:

The arrangement consists of the following parts:

1 Small optical bench	460 41
1 Projection objective	460 13
1 Double-lens condenser with slide holder	460 19
1 Lamp house	460 60
1 Lamp, 6 V, 30 W	450 51
2 Leybold bosses	301 01

441 32

Epidiascope, using 500 W tubular lamp, for brilliant, true-colour projection of opaque objects (prints, drawings, photographs) and slides. When used as episcope an area of 14×15 cm² is fully illuminated. Objects having a length of up to 31 cm can be projected in successive portions by displacing the casing along the base. The object holder can accommodate magazines, etc., of up to 46 cm length and 6.5 cm thickness.

The projector is very easy to convert to a lantern slide projector: by turning a lever, the episcope optical system is closed and the optical system for slide projection is opened. Slides measuring 8.5×8.5, 8.5×10 and 9×12 cm² may be projected.

Optical system for episcope (opaque objects): coated Novo-Trinast-objective 1:3.6, focal length 330 mm. Optical system for diascope (slides): coated Splendar-objective 1:3.6 focal length 200 mm and condenser, dia. 150 mm, as well as additional condenser for increased brilliance.

Complete with the following equipment:

Base with slide rail, tilting screws, securit glass plate for flat objects, eccentric device for pressing objects against the window, double-turbo-blower cooling system for 110 or 220 V A.C., object holder, slide frames for holding slides of the sizes 8.5×8.5 cm², 8.5×10 cm² and 9×12 cm², (two for each size), with switch and cable.

Without lamp; for 220 V, use Cat.No. 441 34
for 110 V, use Cat.No. 441 33

Dimensions: 89 cm long, 29 cm wide, 47 cm high,
weight approx. 18 kp (kg wt)

441 34

Tubular lamp for 220 V; 500 W, for epidiascope (441 32).

441 33

Tubular lamp for 110 V, 500 W, for epidiascope (441 32).

441 51

Projection frame, for plates 9×9 cm² in size, with one circular opening of 150 mm diameter. Particularly suitable for projecting the interference model (415 04), the apparatus for electrical lines of force (545 12) and the flat chamber for ion migration (552 43). Made of plastic, with 4 mm sockets for current supply and with spring holders for attaching it to a lens in frame (e.g. 460 08); for projection we recommend using two such lenses as condenser, as shown in Fig. 43, p. 78.

441 53

Translucent screen, 30×30 cm², plastic plate, with one dull surface, with rod for clamping in a stand base (e.g. 300 02). Particularly recommended for projection and for the study of spectra, interference and diffraction patterns; also useful in only moderately darkened rooms.

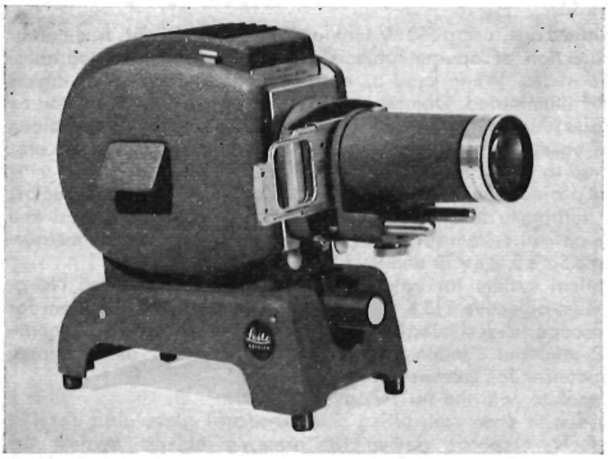
442 90

Holder for base plates (442 60 and 442 61), for the projection by means of an arrangement on the optical bench of apparatus designed for use with the Leitz projector PRADO. For such purposes we particularly recommend the arrangement shown in Fig. 36, p. 72.

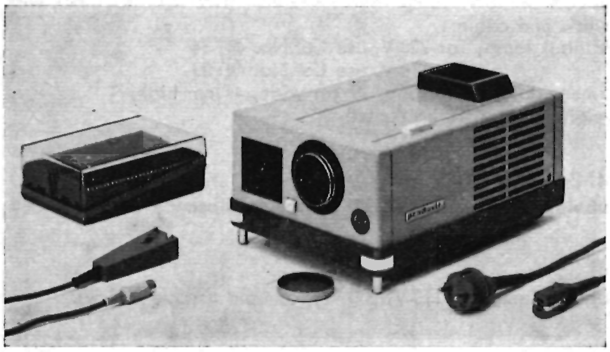
Hexagonal holder on rod, dia. approx. 10 mm, with circular hole, dia. 56 mm, and two spring clips to hold the push-on base plate firmly.

440 00

Book: Dr. H. Kröncke, "Optische Versuche mit Aufbauteilen." This book, which already appears in a third edition, contains detailed descriptions of our optics apparatus and of about 100 experiments. For thorough information beyond the scope of the directions for use. 120 pages, 132 illustrations, cardboard back. (In German only)



442 50



442 91/93

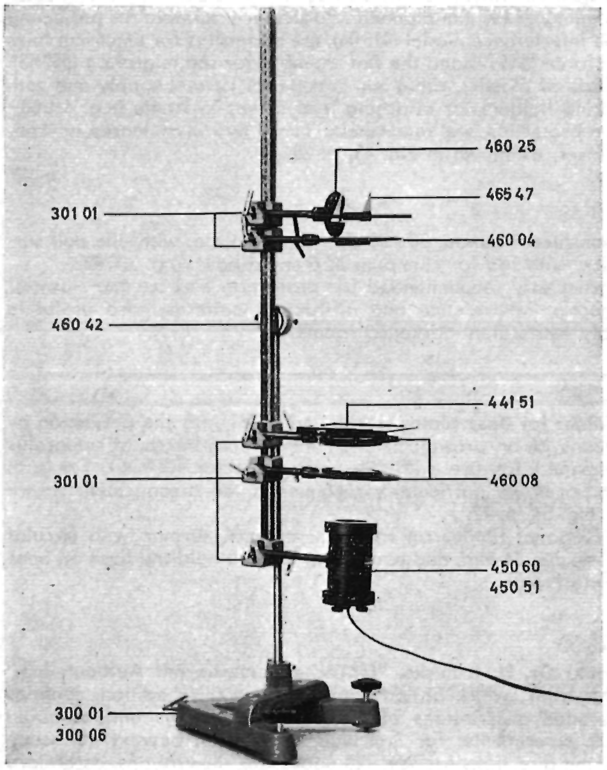


Fig. 43 PH 2029

442 50
Leitz projector PRADO 250, using 250 W lamps, with socket P 28; 110 V, or 220–240 V, with experimental attachment for projecting physical processes and slide holder for projecting slides in 50×50 mm² frames, with objective Hektor 1 : 2.8, focal length 120 mm, and two interchangeable condensers for plane and three-dimensional objects respectively, with approx. 2 m long connecting cable with plug and switch, without lamp; dimensions of case: approx. 22×12×25 cm³, weight approx. 4 kp (kg wt).

442 51
Leitz projector PRADO 500, using lamps up to 500 W, with socket P 28; 110 V, or 220–240 V. Same design as PRADO 250, but with blower cooling system, can be switched for 110, 220–240 V A.C.

Lamps to Leitz projector PRADO 250/500, with socket P 28

442 52
Lamp, 250 W, 220 V.

442 53
Lamp, 250 W, 110 V.

442 54
Lamp, 500 W, 220 V.

442 55
Lamp, 500 W, 110 V.

Lamps for 250 W, 240 V, and 500 W, 240 V, are available on request.

442 91
Leitz projector "pradovit n 12", automatic low-voltage slide projector with remote control of backward and forward slide change and remote focussing; for slides of 50×50 mm² external dimensions (picture size up to 40×40 mm²). With built-in transformer and blower cooling system, can be switched to 110, 120, 130, 220, 230, 240 V, 50–60 c/s, and with 4 m long remote control cable, low-voltage lamp 12 V/100 W (socket Ba 15 s), mains cable with plug, objective Hektor 1 : 2, 2.5/120 mm and lantern slide box containing 2 magazines for 30 slides each.

442 92
Low-voltage lamp 12 V/100 W, with socket Ba 15 s, for "pradovit n 12" (442 91).

442 93
Leitz projector "pradovit n 24", same design as 442 91 but with low-voltage lamp 24 V/150 W; socket G 17 q.

442 94
Low-voltage lamp 24 V/150 W, with socket G 17 q, for "pradovit n 24" (442 93).

You will find more details about the Leitz projectors on p. 101

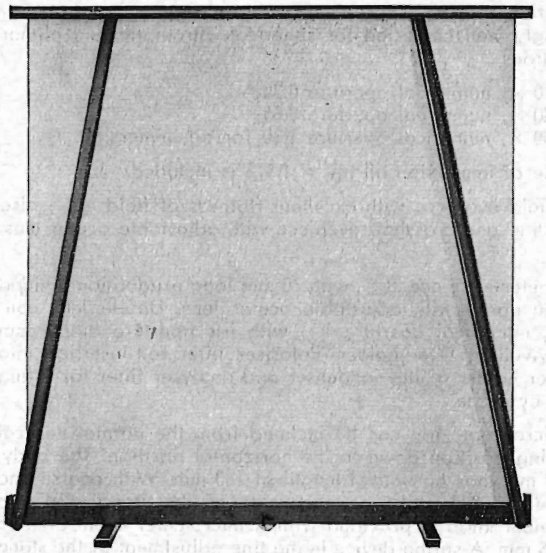
Under an agreement with Messrs. Ernst Leitz GmbH, we manufacture the ancillary equipment for the Leitz projectors PRADO and "pradovit" designed by Professor Bergmann for experiments in mechanics, acoustics, electricity and magnetism. These are described on pp. 101 to 105.

Fig. 43
Projection arrangement, consisting of an optical bench and individual components.
In the arrangement shown, the optical bench is mounted vertically; if required, it may also be arranged horizontally, using the same components.
The arrangement is suitable for projecting the interference model (415 04), the apparatus for electric lines of force (545 12), the flat chamber for ion migration (552 43) or, in a horizontal arrangement, the photoelastic models (471 95) and other polarisation experiments.

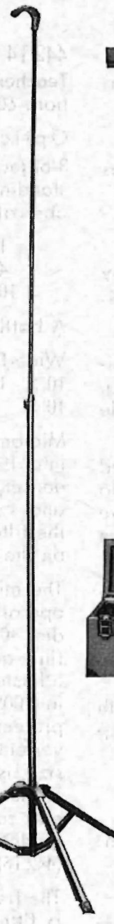
We recommend using the following parts:

1 Stand base, length of sides 28 cm	300 01
1 Optical bench	460 42
5 Leybold bosses	301 01
For illumination:	
1 Lamp with lamp house	450 51/60
As condenser:	
2 Lenses, dia. 75 mm, f = 150 mm	460 08
For projection:	
2 Lens, dia. 40 mm, f = 200 mm	460 04
1 Projection frame	441 51
For deviation:	
1 Prism table	460 25
1 Right-angled prism	465 47

A similar projection arrangement for the ancillary equipment to the Leitz projectors "PRADO" and "pradovit" is described on p. 72.



441 55



441 56

441 57

Size of picture at different distances from lantern to screen

1. **Epidiascope** (441 32)
Projection of opaque objects:
objective epi 3.6/330 mm

Size:	14×15 cm² (enlarged part of object)
Distance in m	Size of picture in m²
4	1.60
5	1.95
7.5	3.00

Slide projection: objective dia 3.6/200 mm

Size:	cm²	cm²	cm²
ext.	8.5×8.5	8.5×10	9 ×12
int.	7.3×7.3	7.3× 8.8	7.8×10.8
Distance in m	Size of picture in m²		
4	1.30	1.60	1.90
5	1.70	2.00	2.50
6	2.00	2.45	3.00
8	2.75	3.30	4.05
10	3.45	4.20	5.15
12	4.20	5.05	6.20

2. **Leitz projectors PRADO** (442 50/51) and **"pradovit"** (442 91/93), objective HEKTOR f = 120 mm

Size:	24×36 mm²	38×38 mm²
Distance in m	Size of picture in m²	
3	0.90	0.95
4	1.20	1.30
5	1.50	1.60
6	1.80	1.90
8	2.35	2.50
10	3.00	3.20
15	4.30	4.60

441 55
Projection screen Planofix, complete with plastic container. Strong, high-quality, cheap small projection screen with simple mechanism.
Projection area: 100×100 cm²; material: Blankana-R, washable.
Mechanism: With the help of two tensioning rods which are introduced into conical slots, the projection cloth can be adequately tensioned to obtain a smooth projection area free from wrinkles.
Mounting: Can be set up on a table by means of feet that can be turned. The tripod stand (Cat. No. 441 56) is only required if the table is not high enough.

441 56
Tripod stand, collapsible like a camera stand; for suspending projection screen Planofix or charts; adjustable height; maximum height (upper edge of projection screen) 2 m above ground level.

441 57
Projection screen Linomat, for convenient and, above all, fast work with larger projection surface; in dust-proof leatherette-covered, elegantly styled transport case. The case has a leather carrier handle and the corners are metal-covered.
Projection area: 130×130 cm²; screen material: Blankana-R, washable.
Mechanism: hinged tensioning rods with high-quality helical tension springs ensure fast unrolling of the screen, automatic collapse and outstandingly plane surface of the screen.
Arrangement: Either directly on a table or the like, or on the floor on built-in feet. The 4 tubular steel feet are coated with a shockproof varnish coat and are completely hidden below the bottom of the transport case. A spring device retains the feet in position both when retracted and when in use.

442 10

School microscope, for simple requirements. Magnification: 50 to 400 ×.

Optical equipment:

2-objective rotatable nosepiece with the achromatic objectives
10 ×, numerical aperture 0.30
and
40 ×, numerical aperture 0.65

The front lens of the objective, 10×, can be unscrewed, whereby the magnification is reduced to 5×; Huyghenian eyepiece, 10×.

Single-lens condenser, numerical aperture 0.7.

The microscope can be tilted from the vertical operating position down to an almost horizontal position. The body, dia. 40 mm, has an optical length of 160 mm. The focussing is made easier by knobs on both sides for the adjustment.

The square stage, approx. 110×110 mm^2 in size, is provided with two removable spring clips. The condenser is screwed into the stage from below. With freely movable plano-concave substage mirror, dia. 30 mm, attached to stand. This may be replaced by a substage lamp (442 19).

Supplied with plastic storage cover. Alternatively, microscope case (442 11) may be used for storage.

442 11

Case for school microscope (442 10), of varnished wood, with carrier handle and lock; approx. 34×16×21 cm^3. Weight 2.2 kp (kg wt).

442 13

Student microscope, for normal requirements, magnification: 50 to 900 ×.

Optical equipment:

3-objective rotatable nosepiece with the achromatic objectives
10 ×, numerical aperture 0.30
30 ×, numerical aperture 0.60
60 ×, numerical aperture 0.85

Huyghenian eyepieces, 5 ×, 10 ×, 15 ×.

Double-lens condenser, numerical aperture 1.1; with iris aperture diaphragm and swivelling filter holder.

The microscope arm may be tilted from the normal vertical operating position down to the horizontal position. The body, dia. 40 mm, has an optical length of 160 mm. With one coarse and one fine adjustment knob on either side of the stand. The latter is provided with a micrometer drum divided in 0.005 mm. A spring device in the fine adjustment of the stand protects the objective lens from damage if the object is inadvertently touched.

The square stage, approx. 110×110 mm^2, is provided with two detachable stage clips. The condenser is fitted into the stage from below and can be displaced along a sleeve. The freely movable plano-concave substage mirror, dia. 50 mm, is attached to the stand, and can be replaced by substage lamp (442 19).

Supplied with polished, brown wood case with lock, key and carrier handle for storing the microscope and ancillaries.

442 15

Attachable mechanical stage, fitting the microscopes listed here (442 10, 442 13 and 442 14); for reproducible fine displacement of slides in two directions at right angles to each other. Range of displacements: 70×45 mm^2.

The slide can be moved within the field of vision of the microscope by means of milled-head knobs and the displacements can be read on vernier scales to 0.1 mm accuracy.

The mechanical stage can be attached to the microscope stage by means of two screws that are supplied with it.

442 14

Teacher's microscope, for advanced requirements; magnification: 60 × to 1,500 ×.

Optical equipment:

3-objective rotatable nosepiece with objectives that are outstandingly well corrected for spherical, chromatic and planar aberrations:

10 ×, numerical aperture 0.30;
40 ×, numerical aperture 0.65;
100 ×, numerical aperture 1.30 for oil immersion.

A bottle of immersion oil n_D = 1.515 is included.

Wide-field eyepiece with excellent flatness of field, 6 ×; also 10 ×, 15 × and crosshair eyepiece with adjustable ocular lens, 10 ×.

Micrometer eyepiece, 8 ×, with 10 mm long graduation divided into 100 parts; with adjustable ocular lens. Double-lens condenser, numerical aperture 1.1; with iris aperture diaphragm and swivelling filter holder. Polariser filter for insertion into the filter holder of the condenser and analyser filter for fitting on the eyepiece.

The microscope arm can be inclined from the normal vertical operating position down to the horizontal position. The body, dia. 40 mm, has an optical length of 160 mm. With coarse and fine adjustment knobs on each side of the stand. The fine adjustment knob is provided with a micrometer drum divided in 0.005 mm. A spring device in the fine adjustment of the stand protects the objective lens from damage if the object is inadvertently touched. The square stage, approx. 110×110 mm^2 in size, is provided with 2 detachable stage clips. The condenser is inserted into the condenser guide of the stage from below and can be moved by a rack and pinion drive. The condenser guide is also suitable for receiving the dry dark field condenser (442 16) and the immersion dark field condenser (442 17).

The freely movable plano-concave substage mirror, dia. 50 mm, is fitted to the stand and may be replaced by substage lamp (442 19).

Supplied with polished wood case with lock, key and carrier handle for storing the microscope and the ancillary items.

442 16

Dry dark field substage condenser, numerical aperture 0.8, for use with the teacher's microscope (442 14), for work with objectives having numerical apertures up to 0.85; in case.

Supplied with frame to protect slides, with iris diaphragm.

442 17

Oil immersion dark field substage condenser, paraboloidal condenser having a numerical aperture of 1.3; suitable for the teacher's microscope (442 14); in case.

Supplied with frame to protect slides, with iris diaphragm.

442 19

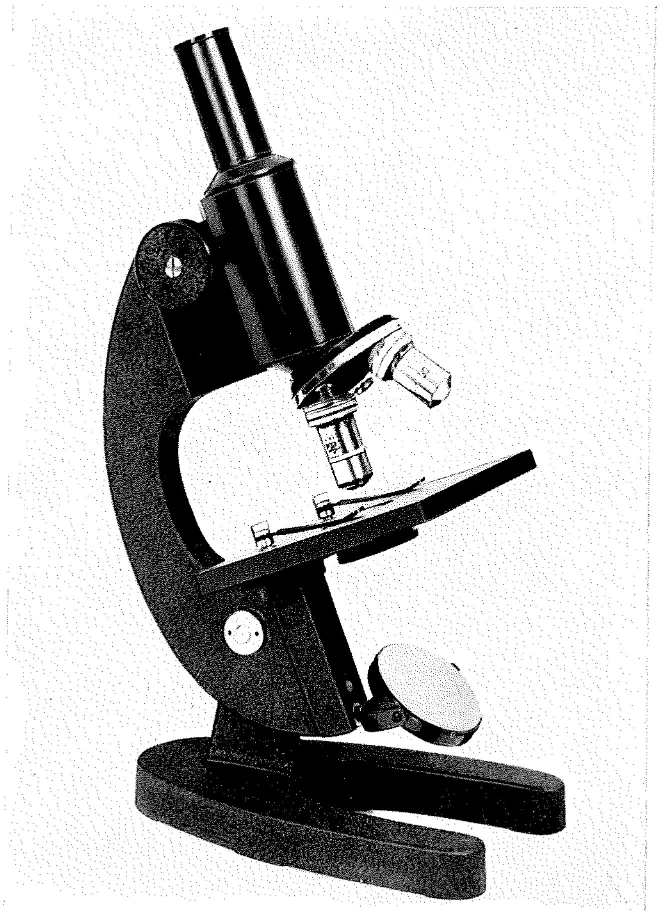
Substage lamp, for mains connection; to be fitted to the teacher's microscope (442 14), the student microscope (442 13) and the school microscope (442 10); with connecting cable, 1.5 m long, switch, blue filter and ground glass; but without bulb.

442 20

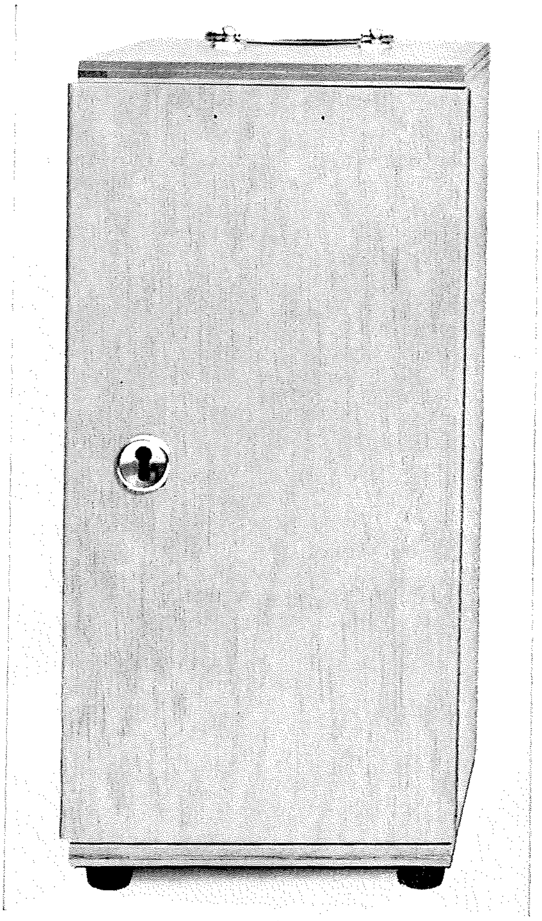
Bulb for 442 19, 220 V, 15 W.

442 21

Bulb for 442 19, 110 V, 15 W.



44210



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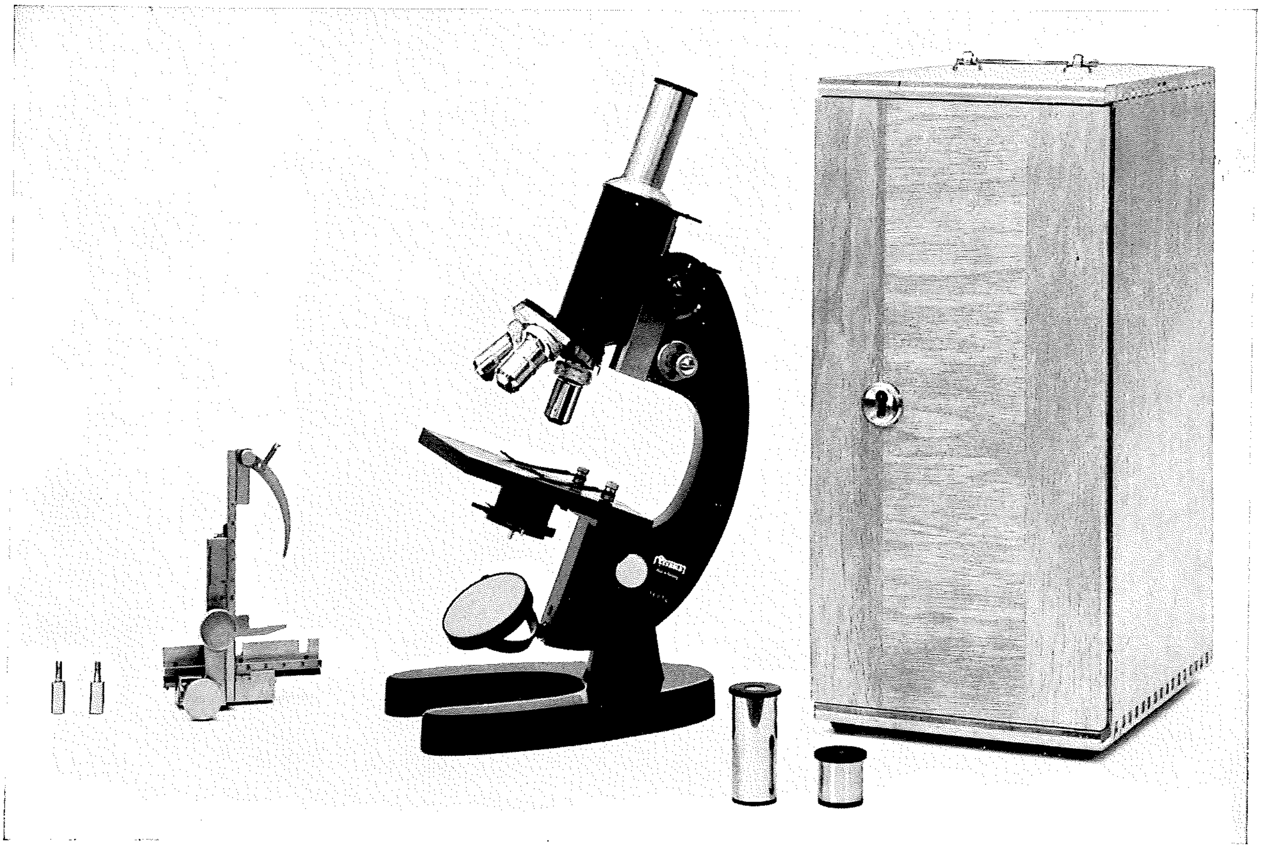
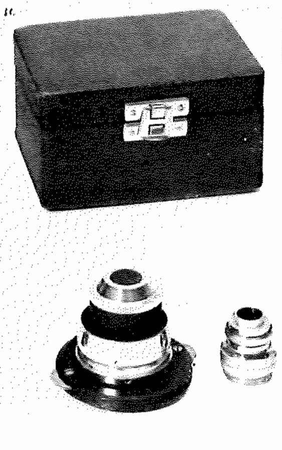


44215

44213

PLATE V

44216



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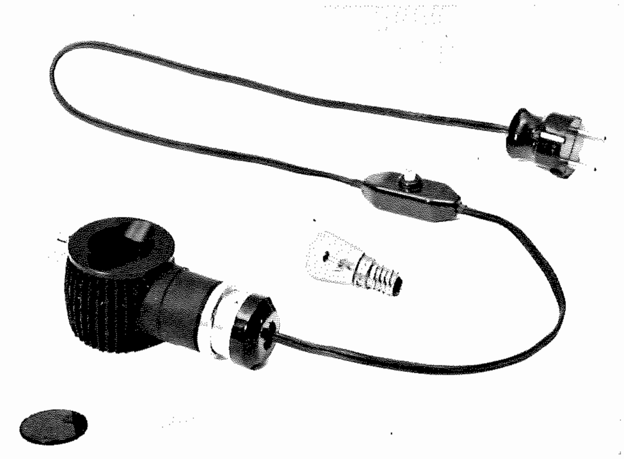
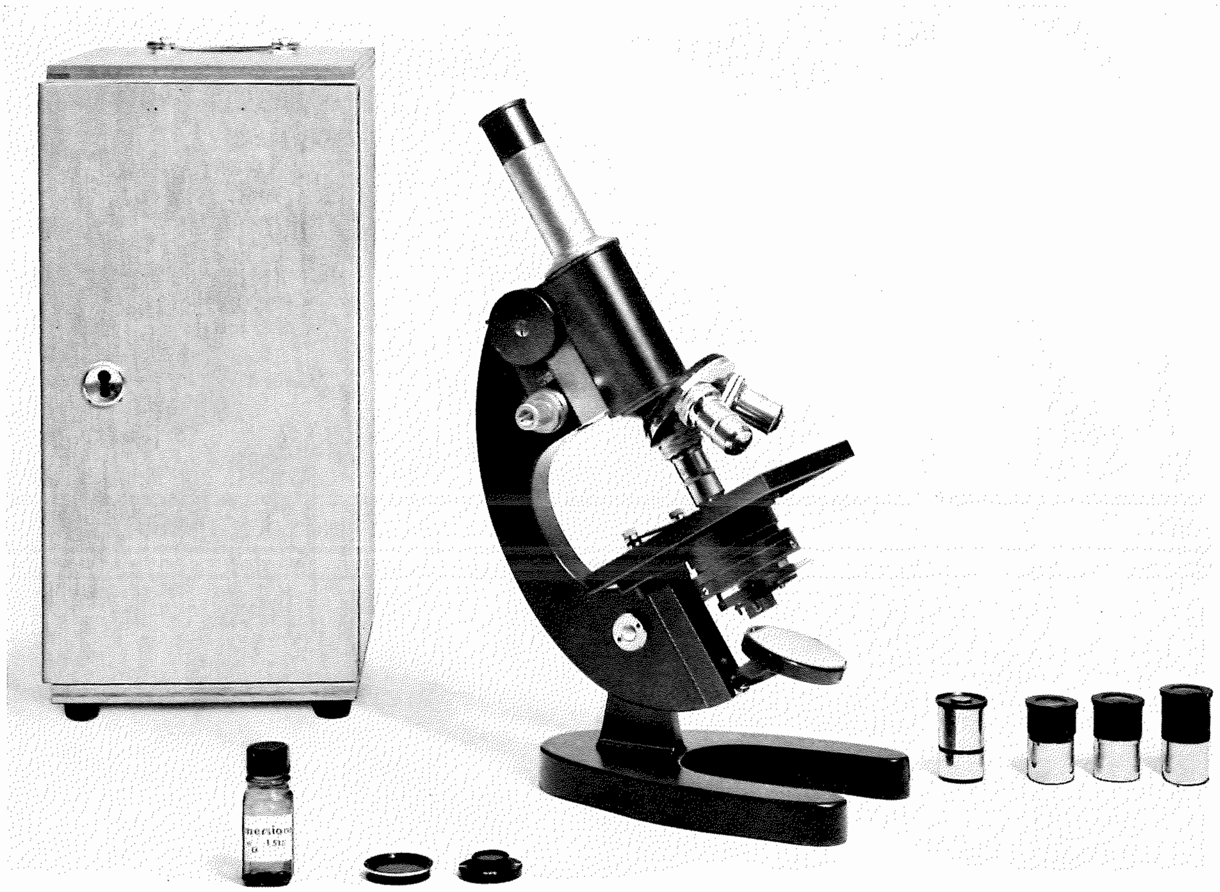
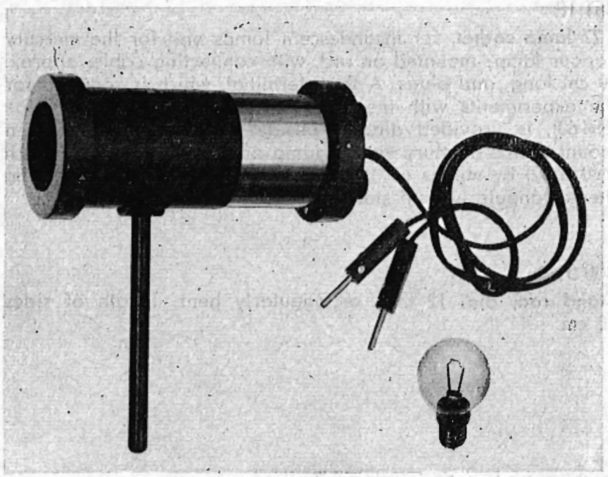


44219 with 44220/21 (middle)

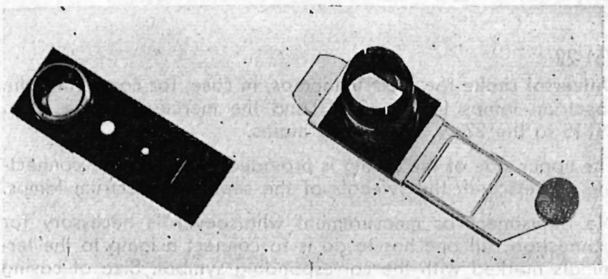


44214

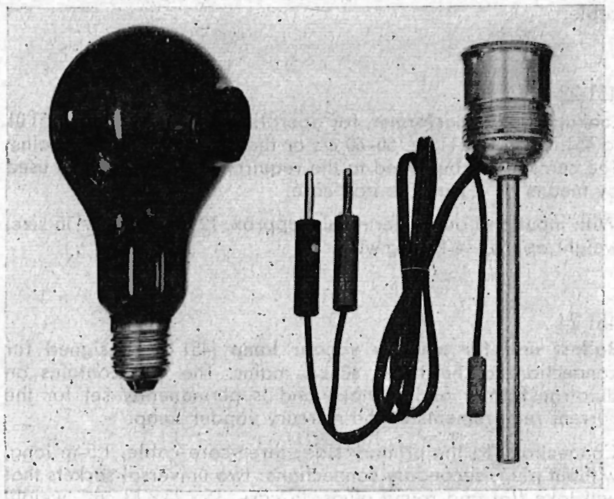
PLATE VI



450 60 450 51



460 17 460 19



451 15 451 18

Spectrum lamps are discharge lamps with incandescent electrodes which emit the line spectra of rare gases and metal vapours with great luminous density, great constancy and spectral purity. These A.C.-operated arc lamps are used for high-intensity spectrum experiments. The lamps contain a glass or quartz burner with the rare gas or metal, the spectrum of which is to be produced. An igniting gas is used to initiate the discharge.

The lamps have special sockets; they are best used in lamp house (451 21). The lamps must be operated from A.C., using a ballast device in series, preferably a choke.

We recommend:

for 220 V, 50 c/s:	Universal choke	451 22
	or Demountable transformer with 1,000 turns coil (can also be used for 240 V, 50 c/s)	562 11/12/15
for 115 V, 60 c/s:	Leakage field transformer (can also be used for 110 V, 50 c/s)	451 23

450 60

Lamp house, for use with lamp (450 51) as source of light in optical experiments, as lamp in a lamp-and-scale assembly, and as illuminating device in other experiments, e.g. cloud chamber or wave trough assemblies. The special advantage of this source of light are the high luminous density of the filament and the simple and accurate adjustment. The lamp house consists of an outer shell and an internal sliding sleeve which carries the socket. The lamp and the socket can be centred exactly by means of 3 thumb screws at the base of the sleeve. Covered cooling slits in the shell are a protection against overheating. In front the lamp house has an opening for inserting a condenser (460 17 or 460 19).

Length of cylinder: pushed in, approx. 11 cm; pulled out, approx. 17 cm. Dia. approx. 60 mm. With Edison E 14 socket and holding rod, dia. 10 mm. Complete with cable and plugs, 1 m long; without lamp and condenser.

450 51

Lamp, E 14 socket, low-voltage lamp for connection to 6 V, 30 W, with filament of small size and high luminous density; for universal use in lamp house (450 60) as a point source of light.

460 17

Single-lens condenser with sliding aperture selector, to be fitted on lamp house (450 60); dia. approx. 40 mm, focal length approx. 45 mm.

460 19

Double-lens condenser with slide holder, to be fitted on lamp house (450 60), dia. approx. 50 mm, focal length approx. 60 mm.

451 15

Mercury vapour lamp, intensive source of light for studying the mercury spectrum in the visible and ultraviolet region, for demonstrating fluorescence and the photoelectric effect with the Wulf electroscope (see p. 132) and for determining Planck's constant. The lamp consists of a quartz tube with sealed-in electrodes housed in an opaque glass bulb with a window through which light emerges. The lamp has an E 27 screw cap; this fits the holder with rod (451 18). The lamp must be operated from A.C., interposing a choke.

We recommend:

for 220 V, 50 c/s:	Universal choke	451 22
	or Demountable transformer with 1,000 turns coil (operating current 1.2 A) (can also be used for 240 V, 50 c/s)	562 11/12/15
for 115 V, 60 c/s:	Series choke (for 50 c/s on special request)	451 24

451 01–11 (Illustration on p. 82)

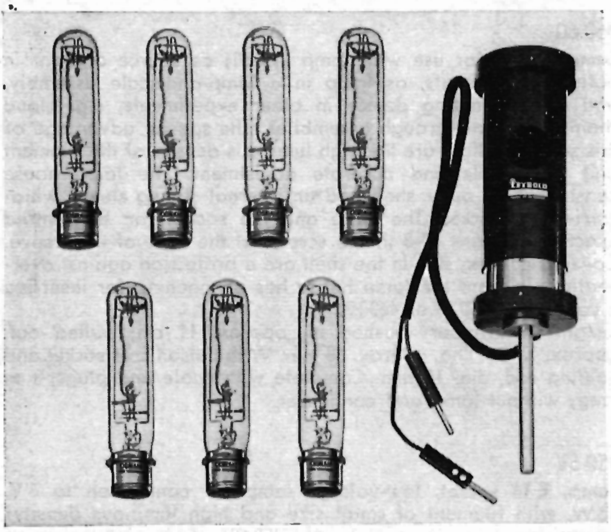
Spectrum lamps

Filling	Ne	He	Cd	Hg	Hg-Cd	Tl	Na
Operating current, A	1.5	1.2	1.5	1.2	1.0	1.0	1.3
Cat.No.	451 01	451 03	451 04	451 06	451 07	451 08	451 11

451 21

Holder for spectrum lamps, for simple and convenient use of spectrum lamps (451 01–451 11) on the optical bench or on a stand.

The holder consists of a base with special socket, and a lamp house with opening that can be turned on the base. On top and at the bottom air slots for cooling are provided; on rod, dia. 10 mm, with connecting cable and plugs. Height without rod approx. 18 cm.



451 01 / 03 / 04 / 06 / 07 / 08 / 11 451 21

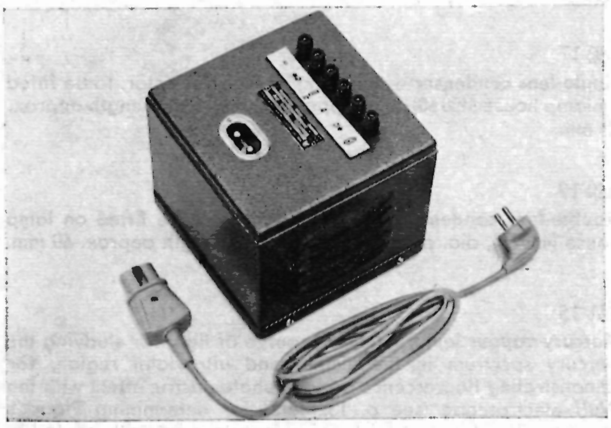
451 18

E 27 lamp socket, for incandescent lamps and for the mercury vapour lamp; mounted on rod, with connecting cable, approx. 70 cm long, and plugs. A third terminal, which is required for the experiments with the field emission electron microscope (554 60), is provided directly beside the lamp socket. When mounting the mercury vapour lamp on the small optical bench (460 41/42) by means of this lamp socket, we recommend using the rectangularly bent stand rod (300 51).

300 51

Stand rod, dia. 12 mm, rectangularly bent; length of sides 10 cm.

Ballast devices for spectrum lamps



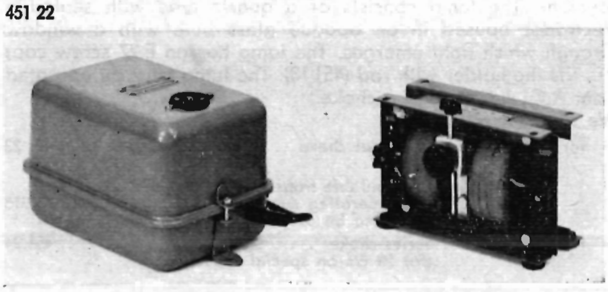
451 22

451 22

Universal choke for spectrum lamps, in case, for connecting the spectrum lamps (451 01–451 11) and the mercury vapour lamp 451 15 to the 220 V, 50 c/s A.C. mains.

The upper side of the casing is provided with a row of connecting sockets with the symbols of the separate spectrum lamps.

No adjustment or measurement whatsoever is necessary for connection; all one has to do is to connect a lamp to the terminals marked with the corresponding symbol. Size of casing approx. 15×18×18 cm³, weight approx. 9 kp (kg wt); with mains cable.



451 24 451 23

451 23

Leakage field transformer, for operating spectrum lamps (451 01 to 451 11) on the 115 V, 50–60 c/s or the 110 V, 50 c/s A.C. mains. The current can be suited to the requirements of the lamp used by means of a variable iron core.

With input and output terminals, approx. 12×12×20 cm³ in size, weight approx. 4 kp (kg wt).

451 24

Ballast unit for mercury vapour lamp (451 15), designed for connection to the 115 V, 60 c/s mains. The unit contains an autotransformer and a choke and is permanently set for the current requirements of the mercury vapour lamp.

Connections to the primary side; three-core cable, 1.5 m long, without plug; secondary connections: two universal sockets that will take flat and round plugs. In case, 15×23×13 cm³, weight approx. 7 kp (kg wt).

On request the unit can also be supplied for 110 V, 50 c/s.

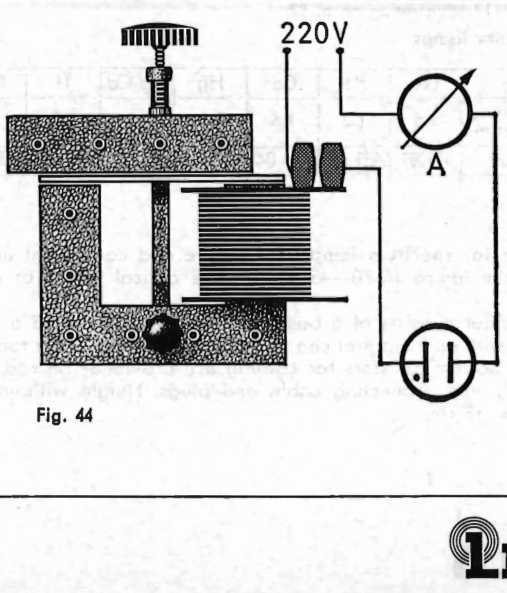


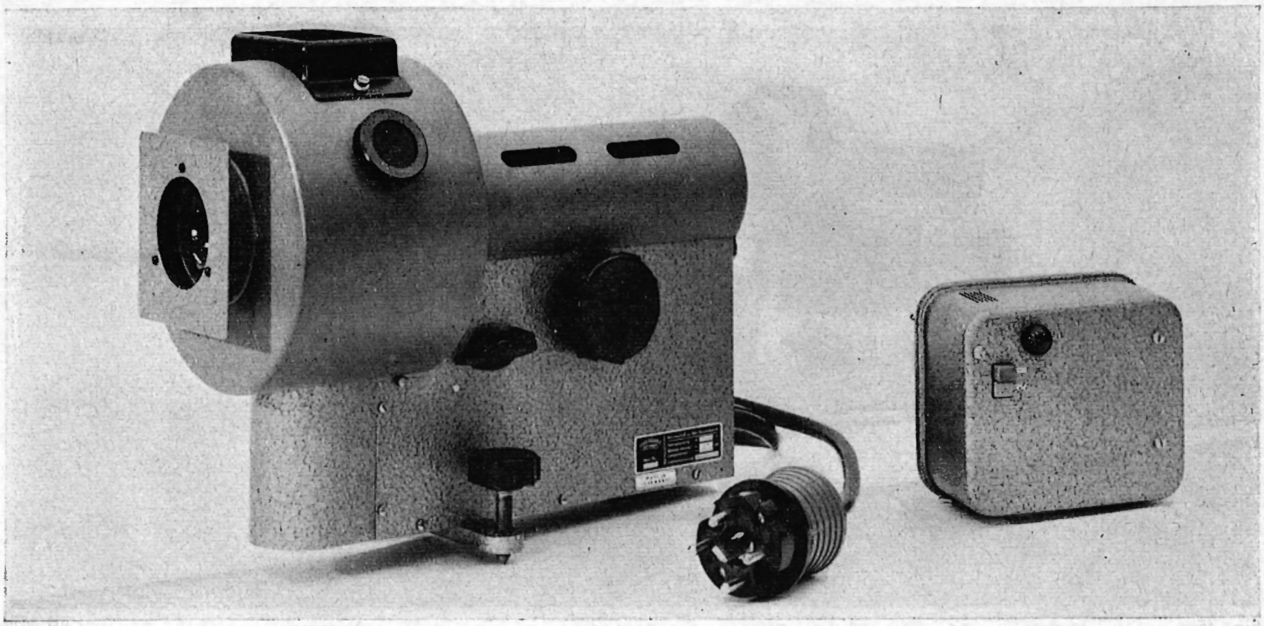
Fig. 44

Fig. 44

Choke for spectrum lamps, assembled from components of the demonstration transformer. With this arrangement the spectrum lamps (451 01–451 11) as well as the mercury vapour lamp (451 15) can be operated from the 220 or 240 V A.C. mains, as the current can be matched to the requirements of the lamp used by displacing the yoke. A piece of cardboard is placed between U-core and yoke.

Parts required:

U-core with yoke	562 11
Clamping device	562 12
Coil with 1,000 turns	562 15



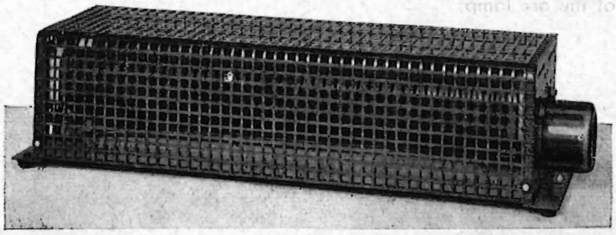
442 32 442 33

442 32

Arc lamp, with double-lens condenser; standard design which can be supplemented by ancillary equipment. Point-shaped source of light of high luminous density, suitable for demonstrating optical phenomena to a large audience and for projection and illuminating devices which require special brightness. This apparatus is very versatile, simple to operate, safe to use, and will therefore stand up to any requirements.

The casing, approx. $32 \times 15 \times 25\ \text{cm}^3$ in size, is closed on all sides, insulated to exclude any risk of electric shock and earthed through the mains cable, with one opening, dia. 65 mm. The two carbons are simultaneously advanced by hand or by means of the automatic feed attachment (442 33/34). With connecting cable, approx. 2 m long, with 5-pin special plug, airing vents, observation window and three-point support with restoring spring, complete with sliding condenser, f = 40 mm, without carbons, automatic feed attachment and ballast resistor.

Please note that the arc lamp must always be operated with a series ballast resistor. Special ancillary equipment has been designed for mounting the arc lamp on the optical benches.



442 37–40

Cat. No.	Resistance	Current	Nominal voltage	Arc voltage	For use with carbons
442 37	17 Ω	10 A	220 V A.C. [2]	50 V	442 35
442 38	6 Ω	10 A	110 V A.C.	50 V	442 35
442 39	27.5 Ω	6 A	220 V D.C.	55 V	442 36
442 40	9 Ω	6 A	110 V D.C.	55 V	442 36
526 08 [1]	25 Ω	5 A	180 V D.C.	55 V	442 47

[1] Without connecting sockets; suitable for switchboard mounting with permanently installed connections using one of the sockets 526 10 or 526 11.

[2] A series-resistor of 19 Ω, which will be supplied on request, is required for connection to 240 V A.C.

442 33

Automatic feed accessory for arc lamp, for 220 to 240 V, 50 c/s *), plug-in unit that fits the standard design of the arc lamp, for automatic carbon advance. The rate at which the carbons are advanced is controlled by the arc voltage. The device works so effectively that a pair of carbons can burn down completely without any readjustment by hand being required. The unit is equipped with a synchronous motor and a combination of control relays and is plugged into arc lamp (442 32).

442 34

Automatic feed accessory for arc lamp, for 110 V, 50 c/s *).

*) For the automatic feed accessory Cat. Nos. 442 33/34, an A.C. supply is required, even if the arc itself is to be supplied with D.C.

526 10 (for illustration, please see p. 120)

Special socket for the arc lamp, for flush mounting; 5-pole socket for permanent wiring-up of the arc lamp connection if the voltage sustaining the arc is obtained from a switchboard (e.g. 526 00/05) and passed through resistor (562 08).

The socket is provided with the following connections: arc voltage, voltage for the automatic feed accessory, and earth line.

526 11 (for illustration, please see p. 120)

Special socket for arc lamp, for surface mounting. Otherwise same as Cat. No. 526 10.

442 37 – 40/526 08

Ballast resistors for the arc lamp (442 32). Wire-wound resistors, with shock-preventing insulation and perforated protective casing. Mains connection in the case of the A.C. resistors (442 37/38): one male plug for the arc voltage and operating voltage of the automatic feed accessory: mains connections in the case of the D.C. resistors (442 39/40): combined 4 mm sockets and screw terminals for the arc voltage, and male plug for the operating A.C. voltage of the automatic feed accessory. On the consumer side, these resistors are provided with a 5-pole socket fitting the plug of the arc lamp, which, correctly wired up, carries an earth line in addition to the above-mentioned voltages. Resistor 526 08 is only equipped with combined 4 mm sockets and screw terminals, and one of the special sockets (526 10 or 11) is additionally required.

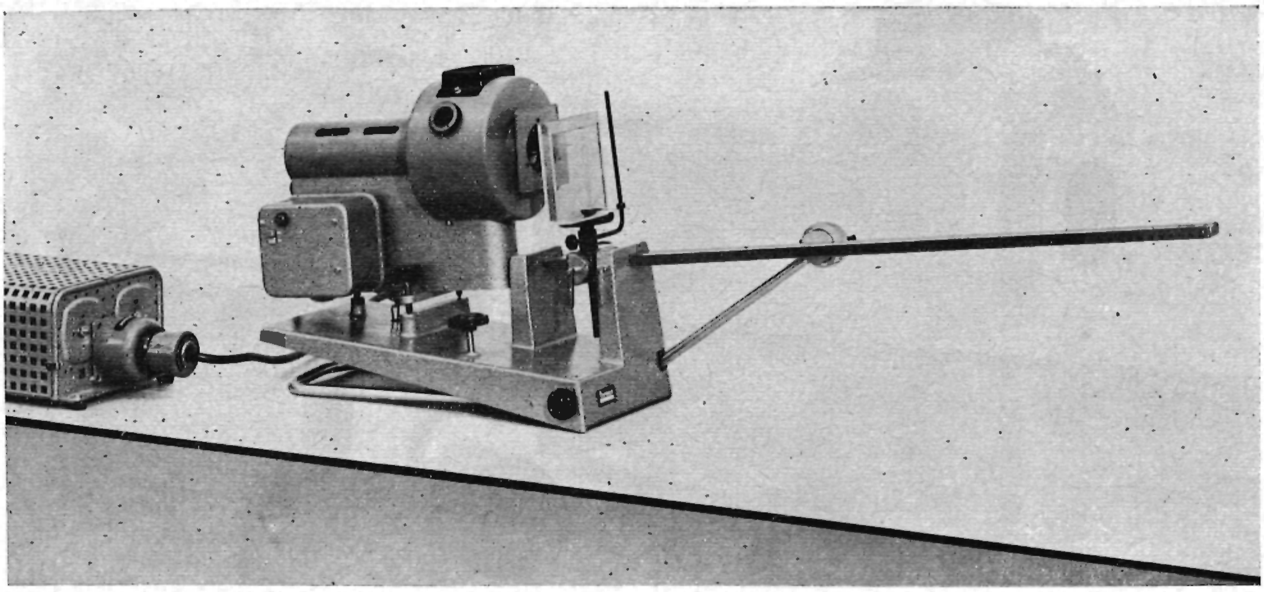


Fig. 45 PH 2030

Arc lamp (442 32) **with automatic feed accessory** (442 33/34) on base (442 44), with small optical bench (460 43) fitted to it, flat glass cell (477 20) filled with copper sulphate solution on prism table (460 25), with condenser lens and ballast resistor (442 37).

442 35

Carbons for arc lamp, 50 pairs of carbons, suitable for A.C., 10 A, for use with series resistor 442 37 or 442 38, consisting of 50 cored carbons, dia. 6 mm, 200 mm long, and 50 cored carbons, dia. 9 mm, 125 mm long.

442 36

Carbons for arc lamp, 50 pairs of carbons, suitable for D.C., 6 A, for use with series resistor 442 39 or 442 40; consisting of 50 homogeneous carbons, dia. 6 mm, 200 mm long, and 50 cored carbons, dia. 7 mm, 125 mm long.

442 47

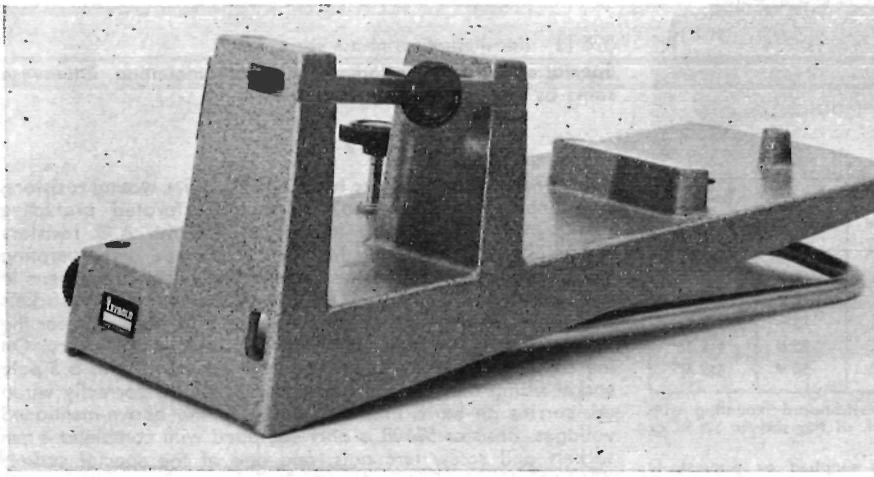
Carbons for arc lamp, 50 pairs of carbons, suitable for D.C., 5 A, for switchboard operation with series resistor 562 08; consisting of 50 homogeneous carbons, dia. 5 mm, 200 mm long, and 50 cored carbons, dia. 6 mm, 125 mm long.

442 44

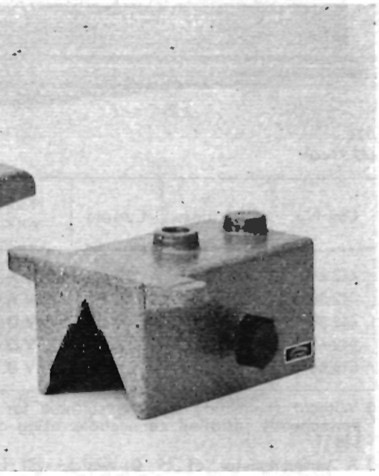
Base for arc lamp, for use with vertical or horizontal projection arrangement and for optical assemblies, where the arc lamp is to be used with one of the small optical benches (460 41/42/43). The base has an area of approx. 40×18 cm^2. In horizontal arrangements, inclinations of up to 15° are possible. With a clamping device in front for mounting a small optical bench (460 41/42/43) which is then in the right position relative to the arc lamp. The small optical bench (460 42) with long side holder is suitable for vertical arrangements. The three-point adjustment of the arc lamp facilitates fine adjustment. Solid cast-iron base, varnished.

442 45

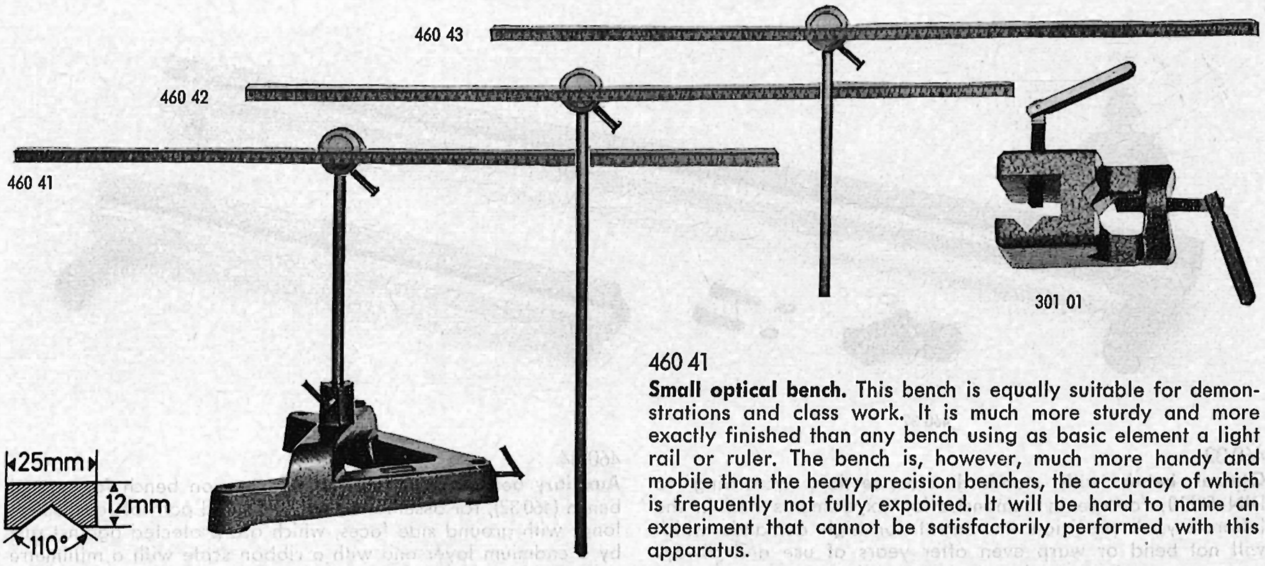
Rider for arc lamp. This rider can be used to mount the arc lamp on an optical bench with standard cross-section (460 32). Cast-iron rider, 125 mm long, with finely finished surfaces of support, setscrew and supports for the three-point adjustment of the arc lamp.

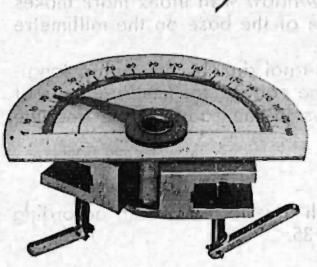


442 44



442 45




460 40

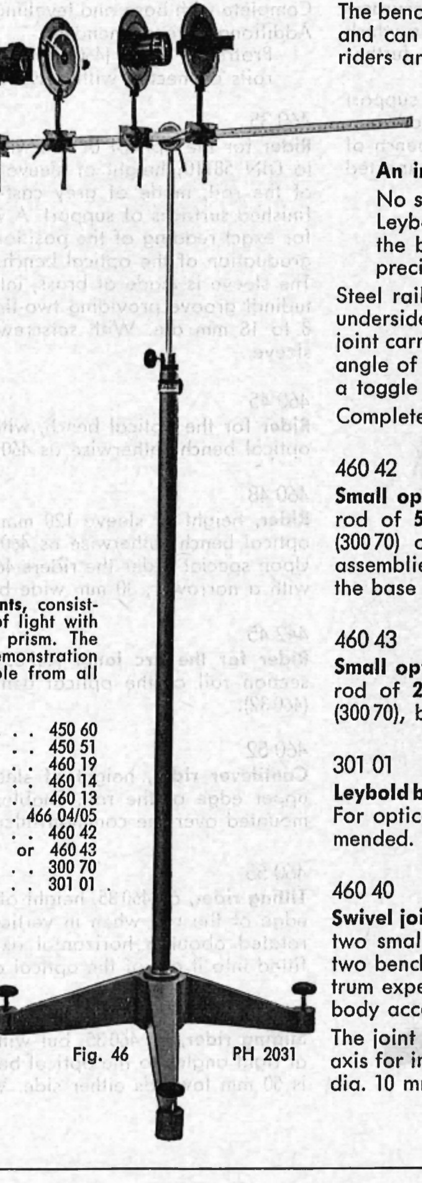


Fig. 46

Arrangement for spectrum experiments, consisting of the following parts: source of light with condenser, slit, objective lens and prism. The optical bench mounted on the demonstration stand is easily accessible and visible from all sides.

Recommended parts:

1 Lamp house	450 60
1 Lamp, 6 V, 30 W	450 51
1 Double lens condenser	460 19
1 Adjustable slit	460 14
1 Projection objective	460 13
1 Direct vision prism with holder	466 04/05
1 Small optical bench	460 42
or	460 43
1 Demonstration stand	300 70
4 Leybold bosses	301 01

460 41

Small optical bench. This bench is equally suitable for demonstrations and class work. It is much more sturdy and more exactly finished than any bench using as basic element a light rail or ruler. The bench is, however, much more handy and mobile than the heavy precision benches, the accuracy of which is frequently not fully exploited. It will be hard to name an experiment that cannot be satisfactorily performed with this apparatus.

The centring of optical arrangements is an easy matter on this bench, since all parts find a firm, non-shifting support and the strong profile of the bench will neither bend nor get distorted. The bench is supported by a rod fitted into a lateral rotary joint and can be adjusted at any desired angle of inclination. The riders are freely displaceable along its entire length.

An important economic consideration:

> No special riders are required for this bench. The standard Leybold boss (301 01) was shaped to match the profile of the bench and meets all demands that can be made on a precision rider for optical purposes.

Steel rail, 75 cm long, 2.5 cm wide, with V-shaped groove on underside, millimetre graduation and laterally attached rotary joint carrying a detachable rod of 25 cm length, dia. 12 mm. The angle of inclination of the rail can be adjusted after loosening a toggle screw, which is afterwards tightened again.

Complete with stand base, length of sides 28 cm.

460 42

Small optical bench, without stand base, with rotary joint and rod of **50 cm** length, for mounting on demonstration stand (300 70) or for vertical arrangement of optical experimental assemblies on a bench clamp (301 06), a stand base (300 01) or the base for the arc lamp (442 44).

460 43

Small optical bench, without stand base, with rotary joint and rod of **25 cm** length, for mounting on demonstration stand (300 70), bench clamp (301 06) or a stand base (300 01).

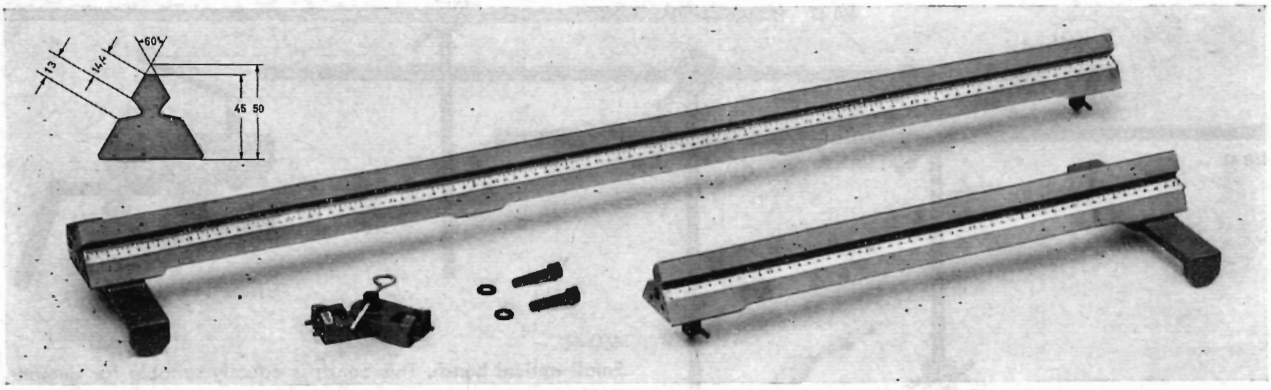
301 01

Leybold boss, as rider for the small optical benches (460 41/42/43). For optical experiments the acquisition of at least 6 is recommended.

460 40

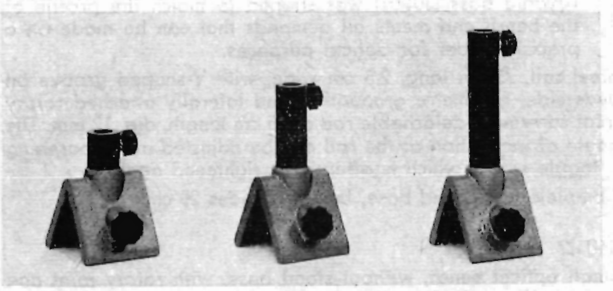
Swivel joint with protractor scale, as swivel connection between two small optical benches (460 41). The angle enclosed by the two benches may be read on the protractor scale, e.g. in spectrum experiments or when measuring intensities with the black-body accessory (389 43) and the thermopile (557 36).

The joint is provided with a hole concentric with the swivelling axis for inserting optical components, e.g. a prism table on rod, dia. 10 mm (460 25).

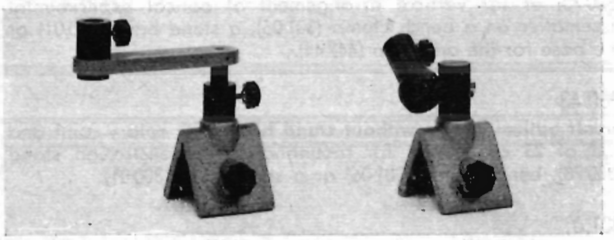


460 32 460 34

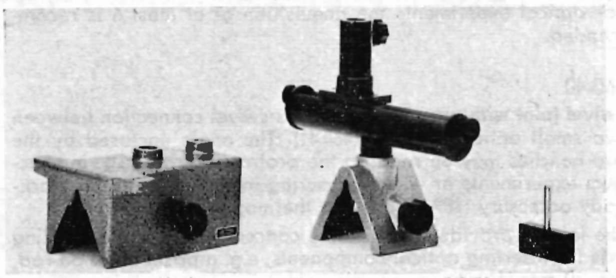
460 32
Optical bench with standard cross-section, according to DIN 58110; for use in demonstration experiments and in the laboratory. A precision instrument for high demands which will not bend or warp even after years of use and always ensures properly centred optical assemblies.
1 m long; triangular section with ground side faces which are protected against rust by a cadmium layer, and with a ribbon scale with a millimetre graduation of ±0.04 mm/m accuracy. The end faces of the bench are provided with holes into which a pin or swivel joint may be inserted for joining on further optical benches.
Complete with base, levelling screw for three-point support and pin screw for attaching further benches. If necessary, several benches can be combined to form an optical bench of greater length. The auxiliary bench (460 34) can be connected by means of a swivel joint.



460 35 460 45 460 48



460 52 460 55



442 45 460 58

460 34
Auxiliary bench with swivel joint, extension bench for optical bench (460 32), for assemblies with deflected path of rays, 50 cm long; with ground side faces, which are protected against rust by a cadmium layer and with a ribbon scale with a millimetre graduation of ±0.04 mm/m accuracy. The swivel joint designed for insertion into the hole in the end face of optical bench 460 32, establishes the swivelling connection of the two benches. Complete with base and levelling screw for three-point support.
Additionally recommended:
Protractor scale (460 67) for reading the angle between the rails connected with a swivel joint.

460 35
Rider for the optical bench, with inverted V section according to DIN 58110; height of sleeve 46 mm above the upper edge of the rail, made of grey cast-iron, 60 mm wide, with finely finished surfaces of support. A window with index mark makes for exact reading of the position of the base on the millimetre graduation of the optical bench.
The sleeve is made of brass, internal dia. 14 mm with a longitudinal groove providing two-line contact for securing rods of 8 to 18 mm dia. With setscrews in the saddle base and the sleeve.

460 45
Rider for the optical bench, with inverted V section according optical bench; otherwise as 460 35.

460 48
Rider, height of sleeve 120 mm above the upper edge of the optical bench; otherwise as 460 35.
Upon special order the riders 460 35/45/48 can also be supplied with a narrower, 30 mm wide base.

442 45
Rider for the arc lamp (442 32), for fitting on the triangular section rail of the optical bench with standard cross-section (460 32).

460 52
Cantilever rider, height of sleeve approx. 80 mm above the upper edge of the rail. Enables objects such as prisms to be mounted over the common fulcrum of two swivelling rails.

460 55
Tilting rider, as 460 35, height of sleeve 90 mm above the upper edge of the rail when in vertical position. The sleeve may be rotated about a horizontal axis in order to turn the object fitted into it out of the optical axis.

460 58
Sliding rider, as 460 35, but with a sleeve that may be shifted at right angles to the optical bench. The range of displacement is 50 mm towards either side. With stop for centring.

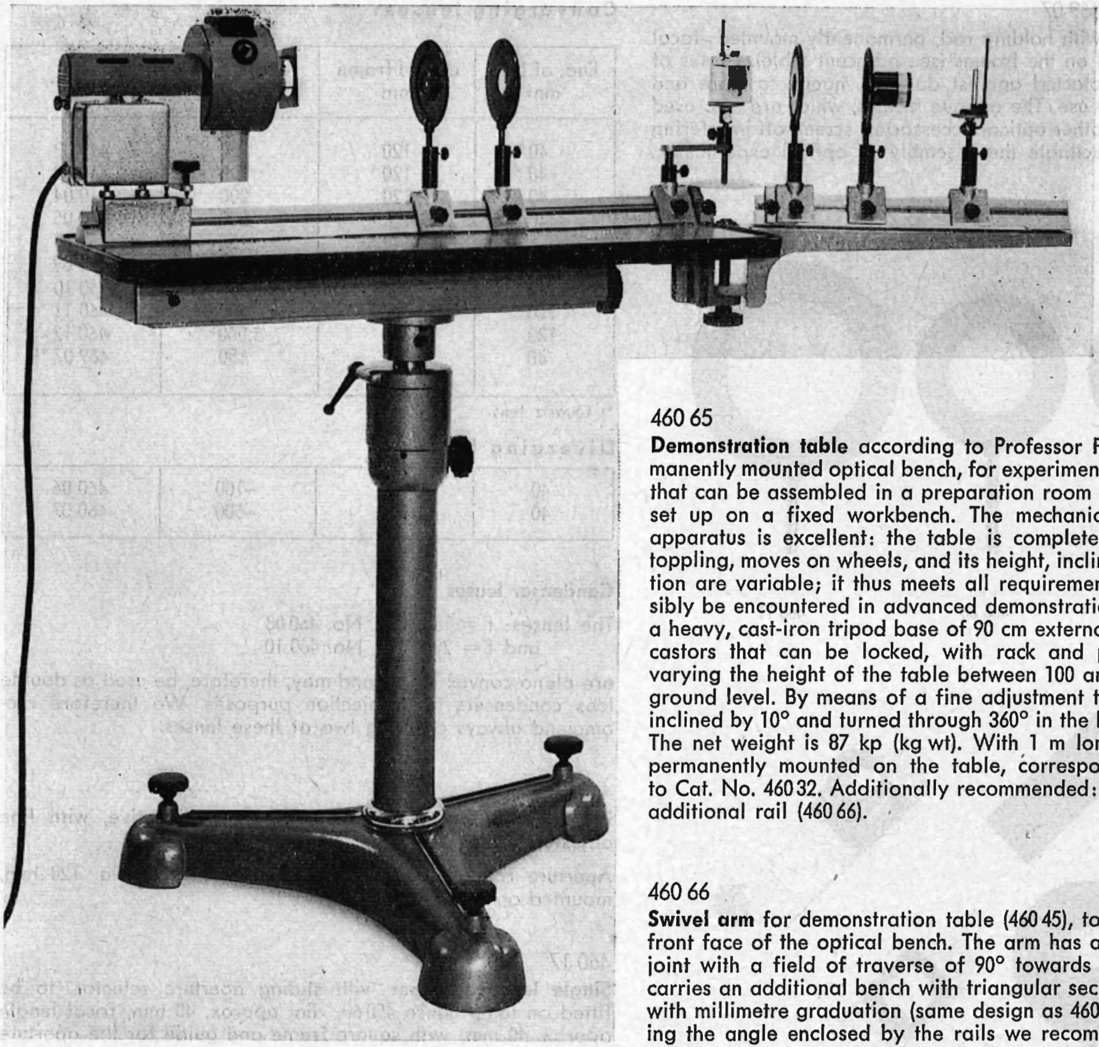


Fig. 47 PH 2032
Projection arrangement for demonstrating complementary spectrum colours on the demonstration table according to Prof. Pohl.

460 65

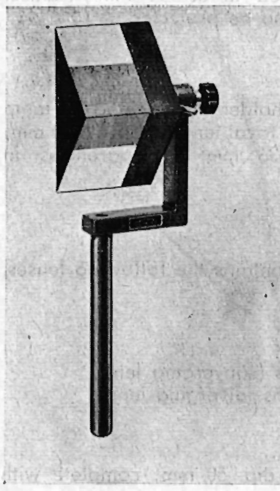
Demonstration table according to Professor Pohl, with a permanently mounted optical bench, for experimental arrangements that can be assembled in a preparation room and need not be set up on a fixed workbench. The mechanical finish of the apparatus is excellent: the table is completely proof against toppling, moves on wheels, and its height, inclination and direction are variable; it thus meets all requirements that can possibly be encountered in advanced demonstrations. Mounted on a heavy, cast-iron tripod base of 90 cm external dia., moves on castors that can be locked, with rack and pinion drive for varying the height of the table between 100 and 140 cm above ground level. By means of a fine adjustment the table may be inclined by 10° and turned through 360° in the horizontal plane. The net weight is 87 kp (kg wt). With 1 m long optical bench permanently mounted on the table, corresponding in design to Cat. No. 460 32. Additionally recommended: Swivel arm with additional rail (460 66).

460 66

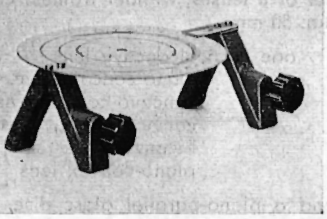
Swivel arm for demonstration table (460 45), to be fitted to the front face of the optical bench. The arm has a lockable swivel joint with a field of traverse of 90° towards either side, and carries an additional bench with triangular section, 50 cm long, with millimetre graduation (same design as 460 34). For measuring the angle enclosed by the rails we recommend protractor 460 67.

The arrangement shown in Fig. 47 consists of the following parts:

Demonstration table according to Pohl	460 65
Swivel arm for demonstration table	460 66
Arc lamp with condenser	442 32
Automatic feed accessory, 220 V	442 33
Rider for arc lamp	442 45
2 Iris diaphragms	460 26
Lens in frame, dia. 40 mm, f = 100 mm	460 03
Hollow prism	465 51
Ethyl cinnamate (for filling hollow prism)	465 55
Protractor and index	460 67
Projection objective	460 13
2 Prism holders	460 25
Narrow prism	465 25
Cantilever rider	460 52
5 Riders	460 45



461 11



460 67

460 67

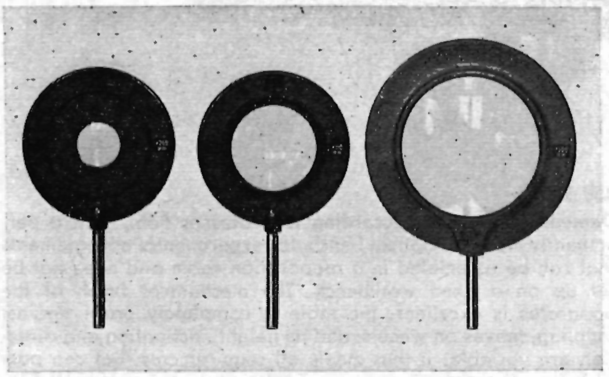
Protractor and **index**, on separate riders, to be fitted on the ends of the triangular section rails (460 32 and 460 34, or 460 65 and 460 66), connected by a swivel joint.

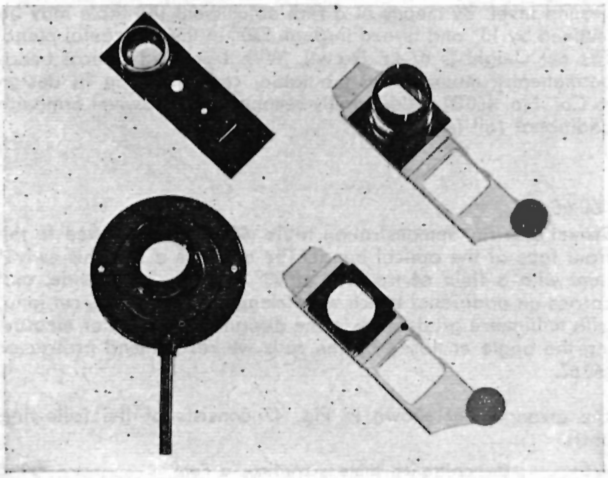
461 11

Right-angled reflecting prism, short sides 70 mm long, height 60 mm, with reflection-coated hypothenuse; on swivel bearings, may be locked in any desired position; on rod, dia. 13.7 mm.

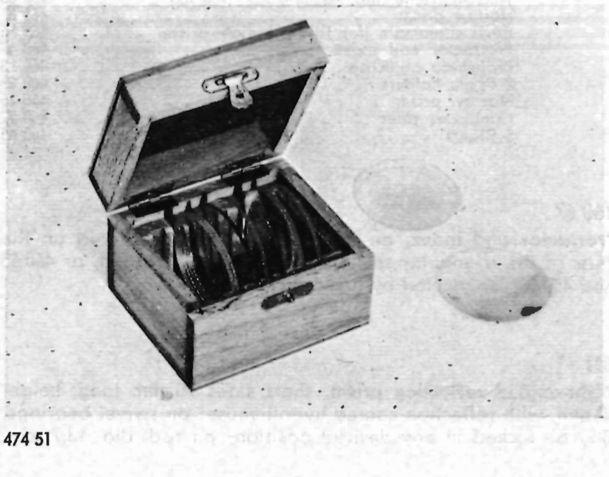
460 02 – 460 12 / 469 07

Lenses in frame with holding rod, permanently mounted: focal lengths engraved on the frames (see adjacent table). Lenses of this type are protected against damage, handy to store and always ready for use. The opaque frames, which are also used for a number of other optical accessories, screen off interfering side light and facilitate the assembly of optical experiments.


460 04 460 08 460 11


460 17
460 13

460 19
460 18


474 51

Converging lenses:

Dia. of lens mm	dia. of frame mm	focal length mm	Cat. No.
40	120	50	460 02
40	120	100	460 03
40	120	200	460 04
40	120	500	460 05
75	120	150	460 08
75	120	300	460 09
120	180	200	460 10
120	180	500	460 11
120	180	5,000	460 12
40	120	150	469 07 *)

*) Quartz lens

Diverging lenses

40	120	–100	460 06
40	120	–500	460 07

Condenser lenses

The lenses: f = 150, Cat. No. 460 08
and f = 200, Cat. No. 460 10

are plano-convex lenses and may, therefore, be used as double lens condensers for projection purposes. We therefore recommend always ordering two of these lenses.

460 13

Projection objective, double-lens coated objective, with fine adjustment tube.

Aperture ratio: 1:3.5; f = 150 mm, in frame, dia. 120 mm, mounted on rod, dia. 10 mm.

460 17

Single lens condenser with sliding aperture selector, to be fitted on lamp house 450 60; dia. approx. 40 mm, focal length approx. 40 mm; with square frame and guide for the aperture selector. The attachment has three circular apertures and one slit.

460 18

Slide holder, to be fitted on single lens condenser (460 17), for the projection of objects mounted in 50×50 mm^2 frames. 24×36 mm^2 transparencies may also be projected.

460 19

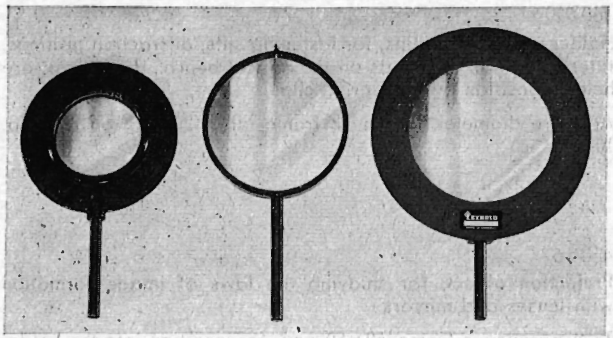
Double-lens condenser with slide holder, to be fitted on lamp house (450 60), dia. approx. 50 mm, focal length approx. 60 mm; complete slide holder for 24×36 mm^2 transparencies in 50×50 mm^2 frames.

474 51

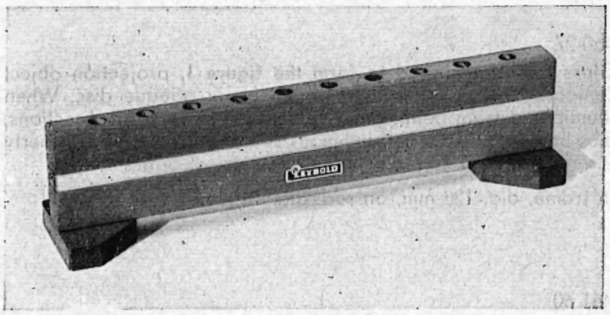
Set of 6 lenses, without frames; contains the following lenses, dia. 50 mm:

one each biconcave lens
plano-concave lens
concavo-convex lens (converging lens)
convexo-concave lens (diverging lens)
biconvex lens
plano-convex lens

and a plano-parallel glass disc, dia. 50 mm; complete with wooden storage box.



463 12 460 28 463 20



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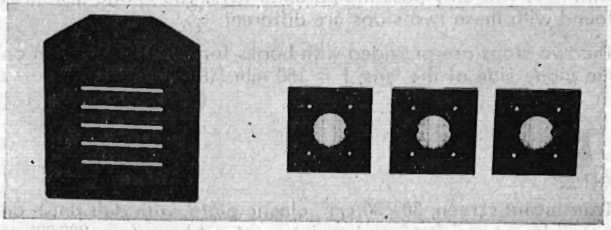
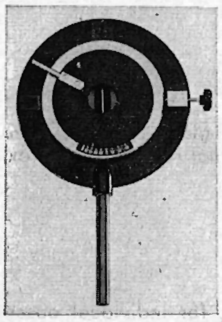
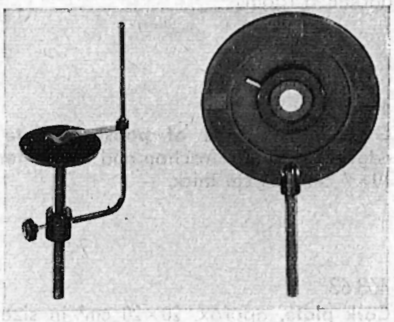


460 24 460 23



460 14



460 25 460 26

305 00
GREEN's lens tissue, especially soft material made of long plant fibres, chemically inactive; for cleaning of lenses and other optical parts and of high-grade insulators; folder holding 50 sheets, size: 20×30 cm².

460 28
Plane mirror, dia. approx. 120 mm, in frame on rod, dia. 10 mm.

463 12
Convexo-concave mirror, two-sided, dia. approx. 70 mm, focal length approx. ±250 mm; front-silvered on the concave side, in frame on rod, dia. 10 mm.

463 20
Front-silvered mirror, ground optically plane, radius of curvature greater than 100 m; coated with aluminium and quartz on the surface, dia. 120 mm, in frame on rod, dia. 10 mm.

For measuring the velocity of light we recommend using two such mirrors since assembly and adjustment of these experiments are much easier with two mirrors than with one.

460 15
Storage rack for lenses in frames and other optical parts with 10 mm stems. Storage in such a rack is highly recommended as it will protect lenses from damage and keeps them always handy to take out. For greater convenience the rack may, moreover, be provided with lateral inscriptions.

Wooden rack, approx. 33 cm long, with 10 holes, dia. 10 mm, supports and writing strip.

460 14
Adjustable slit, both edges displaceable, suitable for all experiments in diffraction and interference, and for spectral experiments. A fact that renders adjustment particularly convenient: the slit can be rotated within the frame and locked in any desired position by means of a knurled-head screw.

Height of slit 20 mm; opening lever with scale of slit width graduated from 0 to 1.6 mm; in frame, dia. 120 mm, on rod, dia. 10 mm.

460 23
Set of 3 slits, for interference and diffraction experiments; slit widths: 0.5; 0.25; 0.12 mm; each slit in metal frame, 50×50 mm².

For insertion into the holder with spring clips (460 22).

460 24
Attachment with 5 slits, for singling out parallel rays of light, especially for experiments with the optical disc (463 52).

The central beam is white, the outer ones are red or green, the slits being covered with laminae of these colours.

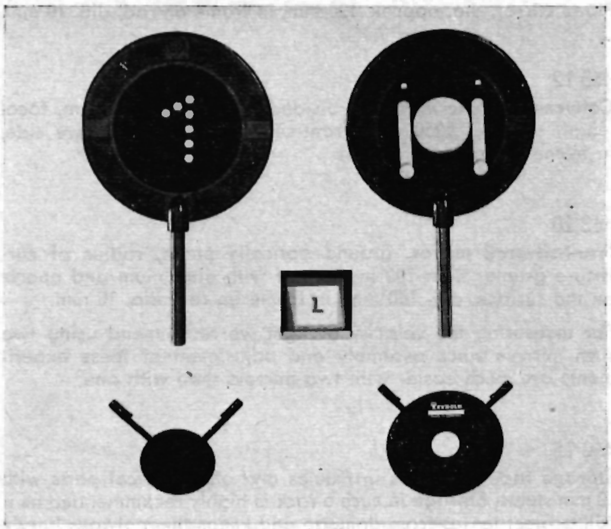
The attachment is hung against the plane side of lens (460 08) which renders the incident light parallel.

460 25
Prism table with holder, for mounting prisms, plate glass cells and similar objects on the optical bench. A sprung arm with rubber-covered tip will hold these parts so securely that the optical bench may even be set up vertically.

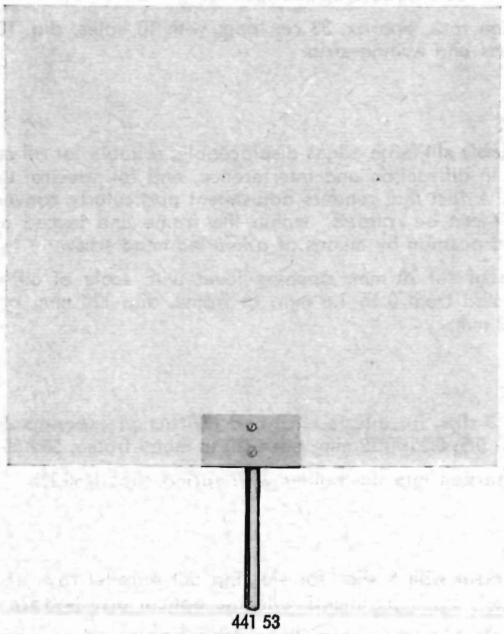
The plate, dia. approx. 60 mm, is covered with felt and is mounted on a rod of 10 mm diameter. Objects of up to 10 cm height can be secured to it.

460 26
Iris diaphragm, maximum aperture 30 mm diameter; in frame, dia. 120 mm, on rod, dia. 10 mm.

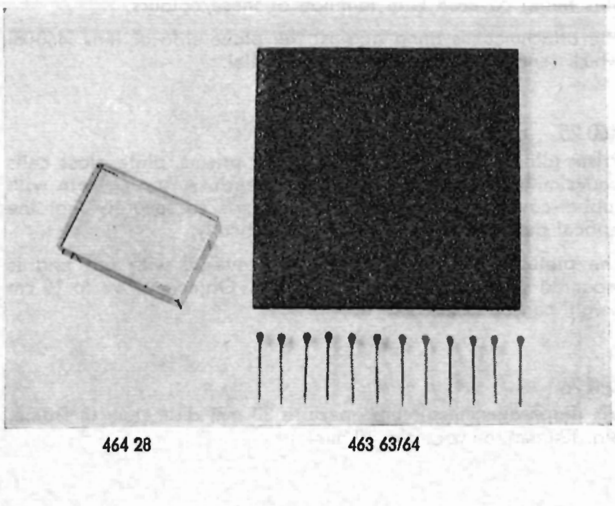
460 27 460 16 460 22



461 60



441 53



464 28 463 63/64

460 22
Holder with spring clips, for fastening slits, diffraction gratings, filters etc. in experiments on the optical bench. The objects are held in position by two spring clips.

Aperture diameter 40 mm, in frame, dia. 120 mm, on rod dia. 10 mm.

460 16
Projection object, for studying the laws of image formation with lenses and mirrors.

Transparency in frame, 50×50 mm², for insertion into the holder with spring clips (460 22).

460 27
Glass beads arranged to form the figure 1, projection object composed of glass beads mounted in an opaque disc. When illuminated from behind, the beads emit light in all directions, thus behaving like a self-luminous source of light. This property is very useful in experiments in geometrical optics.

In frame, dia. 120 mm, on rod, dia. 10 mm.

461 60
Pair of stops for spherical aberration, to study the image forming properties of uncorrected, large-diameter lenses. The disc-shaped stop will only pass the marginal rays and the stop with hole will only pass the paraxial rays. The image distances found with these two stops are different.

The two stops are provided with hooks for suspending them on the plane side of the lens, f = 150 mm (460 08).

441 53
Translucent screen, 30×30 cm², plastic plate, with dull finish on one side, on rod for insertion into a stand base (e.g. 300 02) or a Leybold boss (e.g. 301 01). Specially recommended for projection purposes and for the observation of spectra and interference and diffraction phenomena, also in only moderately darkened rooms.

464 28
Glass plate made of polished plate glass, with bevelled edges, to study refraction and total internal reflection; approx. 10×7 cm², 2.5 cm thick.

463 63
Cork plate, approx. 20×20 cm² in size, for individual observation of reflection and refraction. The path of rays is marked with pins and measured afterwards.

Supplied without pins.

463 64
Set of 12 pins for cork plate (463 63), approx. 5 cm long, with large heads.

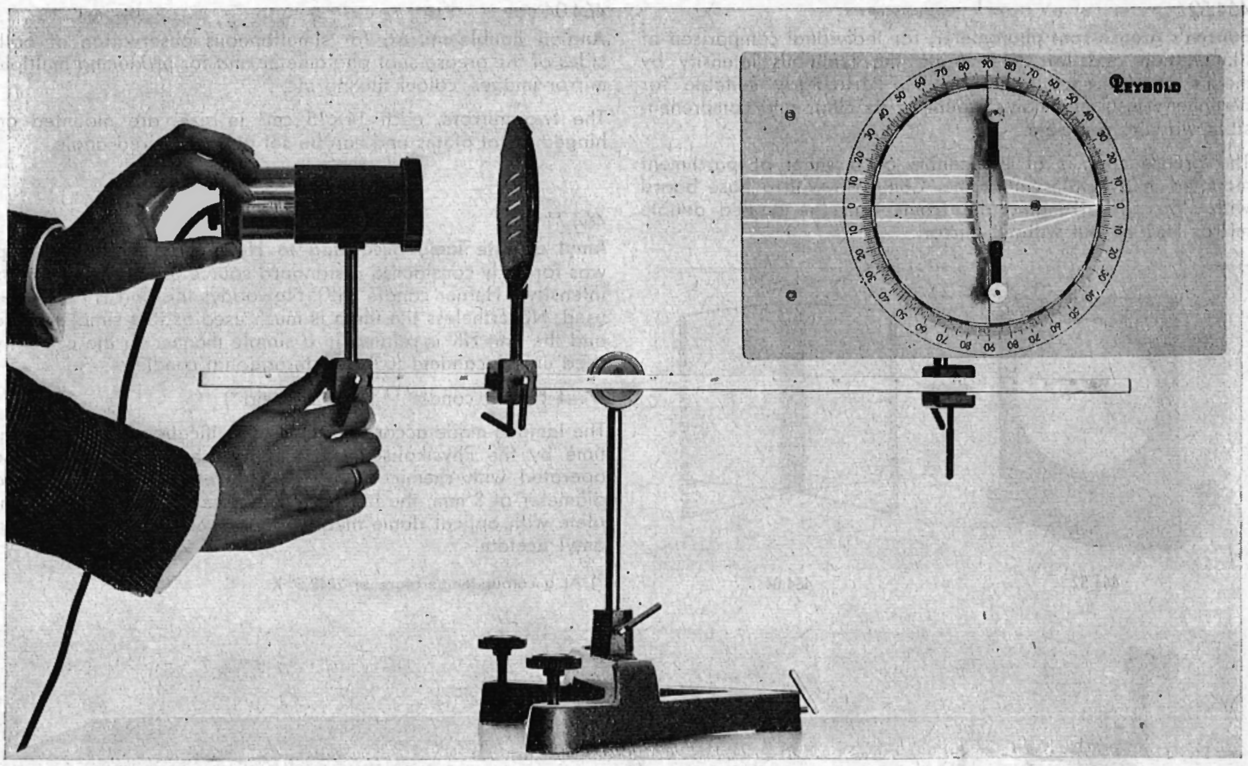


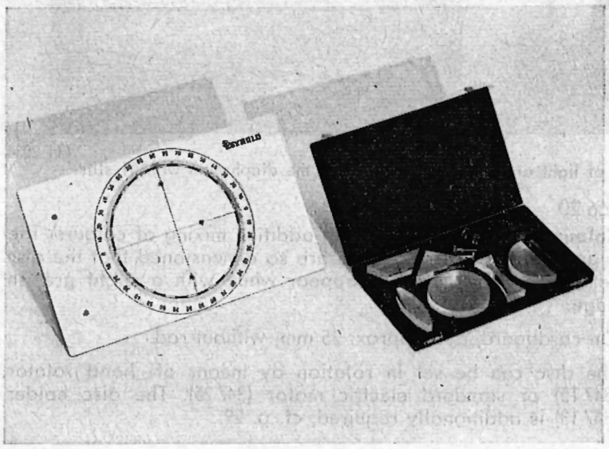
Fig. 48

PH 2033

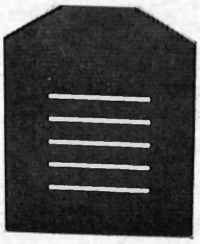
An assembly with the optical disc, using the optical bench and other accessories.

We recommend:

1	Small optical bench	460 41
1	Illuminating device	450 60/51
1	Lens in frame	460 08
1	Attachment with 5 slits	460 24
4	Leybold bosses	301 01
1	Stand rod, 25 cm long	300 41



463 52



460 24

463 52

Optical disc, for experiments on reflection and refraction of light using narrow beams which graze the disc and pass through the experimental body on their way. These experiments are simple and convincing and therefore of great value in the introduction to geometrical optics.

Disc, 40×25 cm² in size, varnished white, with circular scale divided in degrees, holes for fitting the holder for the experimental objects, and a rod for mounting the disc. Complete with one set of accessories in case, consisting of:

1 Plane mirror
1 Convexo-concave mirror
1 Trapezoidal plate
1 Circular semicylinder
1 Circular cylinder
1 Right-angled prism
1 Biconvex cylindrical lens
1 Biconcave cylindrical lens
2 Sprung holders

These elements for demonstrating the refraction of light are made of transparent, unbreakable plastic. Without illuminating device and stands.

(See "LEYBOLD Physics Leaflets" DC 535.311; a, DC 535.312.1; a, DC 535.314; a, DC 535.316; a and b).

460 24

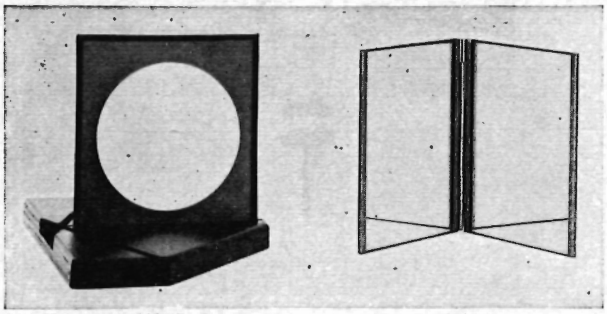
Attachment with 5 slits, for singling out parallel rays of light, especially for experiments with the optical disc (463 52). The central beam is white, the outer ones are red or green, the slits being covered with laminae of these colours.

The attachment is suspended against the plane side of lens (460 08) which renders the incident light parallel.

464 52

Bunsen's grease-spot photometer, for individual comparison of illumination and for determining the luminous intensity by means of reference light sources. Particularly suitable for beginner's instruction on account of its clear and comprehensible working principle.

The grease spot is at the centre of a sheet of parchment mounted in a 14×15 cm² frame. Complete with a base board with slots for arranging the frame and the angled double mirror (464 04), but without mirror.



464 52 464 04

464 04

Angled double mirror, for simultaneous observation of both sides of the grease-spot photometer and for producing multiple mirror images, colour mixing etc.

The two mirrors, each 14×15 cm² in size, are mounted on hinged metal plates and can be set at any desired angle.

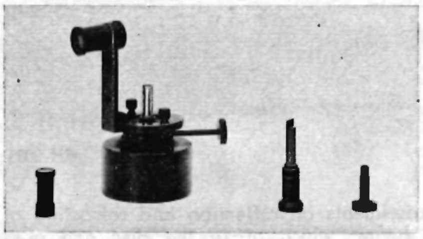
464 71

Amyl acetate lamp according to Hefner-Alteneck. This lamp was formerly considered a standard source of light of luminous intensity 1 Hefner candle (HK). Nowadays this unit is no longer used. Nevertheless the lamp is much used as it is simple to use and the unit HK is related in a simple manner to the currently used unit, 1 candela (cd) or international candle:

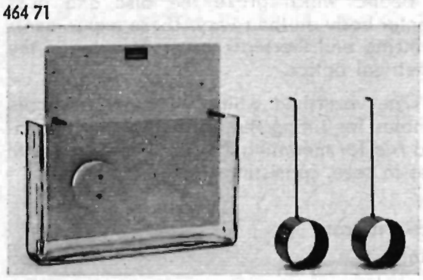
1 Hefner candle = 0.903 candela *)

The lamp is made according to the specifications issued at that time by the Physikalisch-Technische Reichsanstalt. It must be operated with chemicall pure amyl acetate, the wick has a diameter of 8 mm, the height of the flame is adjustable. Complete with optical flame measure and checking gauge, without amyl acetate.

*) At a colour temperature of 2042.5° K



464 71



464 26

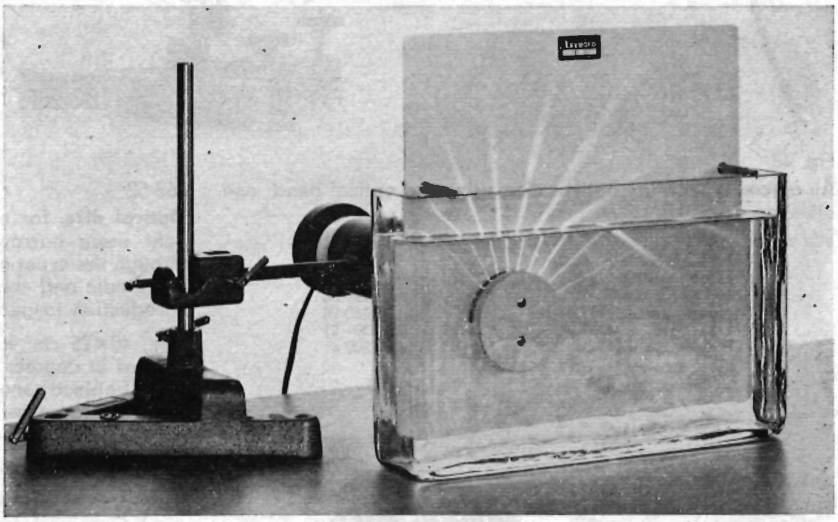


Fig. 49 PH 2034
Refraction and reflection of light at a water surface, using the diaphragm with 11 slits.

464 26

Apparatus for demonstrating refraction and reflection at a water surface, to study the refraction and reflection phenomena as a beam of light passes from water into air at various angles of incidence. The beam of light is produced by reflection at a conical, polished metal mirror and limiting by means of a slit diaphragm that can be turned to obtain different angles of incidence.

The ray grazes along a white plate and its path from the water into the air can be followed. A second slit attachment can be substituted for the first; this will produce 11 rays simultaneously which emerge at different angles.

Complete with white, varnished plate, approx. 27×26 cm² in size, with conical mirror and diaphragm holders and two slit diaphragms and a glass cell, approx. 36×18×5 cm³ in size, without illuminating device.

We recommend (cf. Fig. 49)

1 Lamp house	450 60
1 Lamp, 6 V, 30 W	450 51
1 Single-lens condenser	460 17
and Stand material	

466 20

Colour disc, for demonstrating additive mixing of colours. The segments in different colours are so dimensioned that the disc set in rapid rotation will appear white with a slight greyish tinge.

On cardboard, dia. approx. 25 mm, without rod.

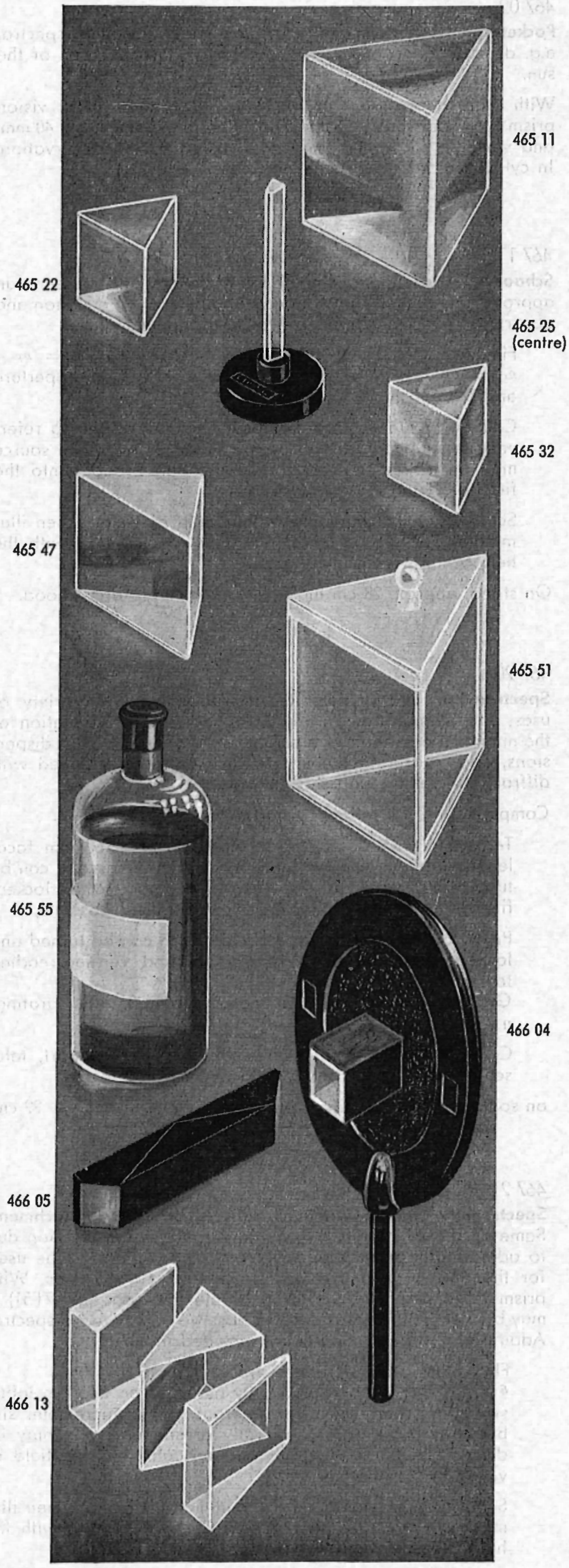
The disc can be set in rotation by means of: hand rotator (347 15) or standard electric motor (347 25). The disc holder (347 13) is additionally required, cf. p. 29.

469 17 (not shown)

Quartz glass prism, equilateral, edge length 30 mm; for spectral dispersion of light in the ultraviolet region. The two polished prism faces are plane to 0.5 nm.

471 51 (not shown)

Simple line grating, for spectral dispersion, see p. 97.



465 11

Pressed glass prism, for simple spectrum experiments, equilateral, length of sides approx. 50 mm, approx. 60 mm high.

465 22

Crown glass prism, equilateral, sides 30 mm long, $n_D = 1.516$, $n_F - n_C = 0.008$.

465 25

Narrow prism, for the colourful and impressive experiments on complementary colours. The prism is used to deviate out individual colours from a spectrum which can be recombined to form white by means of a lens. The deviated colour appears on the screen side by side with the recombined rest of the spectrum which will now add up to form the complementary colour.

Approx. 50 mm high, 5 mm wide, on base for fastening on the prism table (460 25). The experiment will succeed best when using the direct vision prism (466 05).

A detailed description of this experiment will be found in LEYBOLD Physics Leaflets, DC 535.621.1; a

465 32

Flint glass prism, equilateral, sides 30 mm long, $n_D = 1.620$; $n_F - n_C = 0.017$.

Recommended as an early acquisition, this prism being much used in spectrum experiments.

465 47

Right-angled prism, isosceles, length of shorter sides 40 mm, 40 mm high; for the inversion of images, without changing the direction of the path of rays, and for changing the direction in case of horizontal projection.

465 51

Hollow prism, equilateral, 60 mm long; made of plate glass plates, with ground-in stopper, for filling.

We recommend filling this prism with ethyl cinnamate which has a high dispersion and is neither inflammable nor poisonous.

465 55

Ethyl cinnamate (C_6H_5-CH=CH-$COOC_2H_5$), for filling the hollow prism, bottle containing 200 g.

466 05

Direct vision prism, particularly suitable for experiments on the optical bench; in spite of its great dispersion, the beams of light passing through it do not change their direction. We recommend this prism for many spectrum experiments, e.g. line spectra, inversion of the D-line, complementary colours and determination of Planck's constant.

Consists of 3 single prisms, cross-sectional area 20×20 mm², length 10.2 cm, $C - F = 4°14'$.

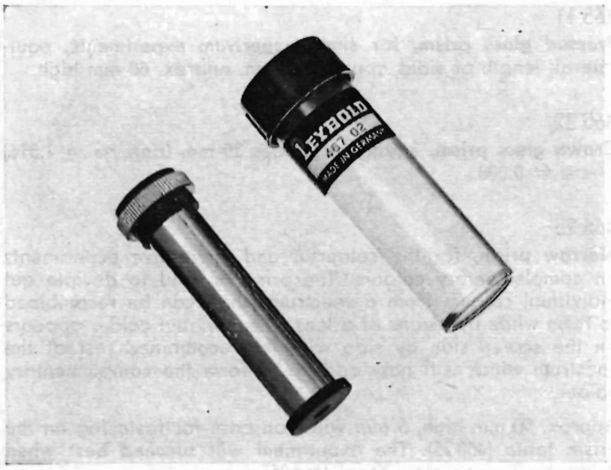
466 04

Holder for direct vision prism. The opening is so arranged that in the case of assembly on the optical bench, the centre of the refracting surface of the direct vision prism coincides with the optical axis of the assembly.

With frame, dia. 120 mm, on rod, dia. 10 mm.

466 13

Set of three prisms, each with 40 mm long sides, height 40 mm. Suitable for assembling an achromatic prism to explain the correction of chromatic aberration, and for assembling a direct vision prism.

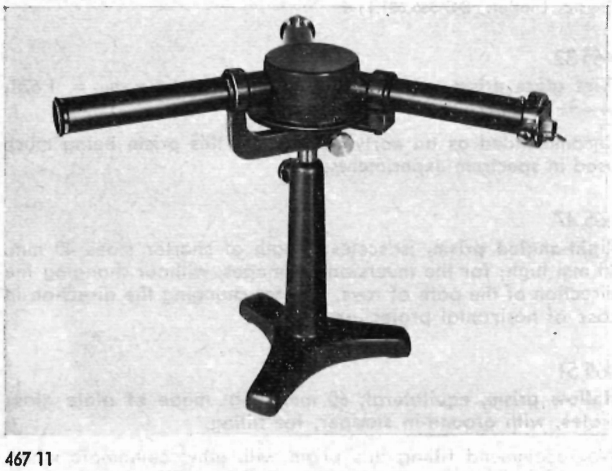


462 02

467 02

Pocket spectroscope, handy instrument for observing spectra, e.g. demonstration of Fraunhofer lines in the spectrum of the sun.

With tube, telescopic, approx. 8 cm long, and direct vision prism of dispersion $n_F - n_C = 0.02628$; with eyepiece, f = 40 mm, and variable slit, which can be adjusted during observation. In cylindrical case with screw-on lid.



467 11

467 11

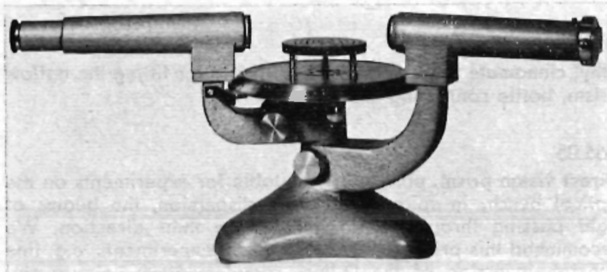
School spectroscope designed by Kirchhoff and Bunsen, an approved instrument for observing and measuring emission and absorption spectra, complete with the following parts:

Flint glass prism, 60°, length of base 30 mm, $\vartheta = n_F - n_C = 0.017$; with telescope, eyepiece with 20 mm aperture and 160 mm focal length.

Collimator tube with micrometer slit and swivelling reference prism by which light from a laterally arranged source may be dispersed into a spectrum and brought into the field of vision for comparison.

Scale tube, scale appears within field of vision when illuminated, can be used to determine wavelengths with the help of known spectral lines.

On stand, approx. 28 cm high; with detachable prism hood.



467 20

467 20

Spectrometer and goniometer, instrument with a variety of uses; for example, measuring prism angles, determination of the minimum deviation of a prism, of refractive indices, dispersions, and measuring the interference patterns obtained with diffraction gratings and slits.

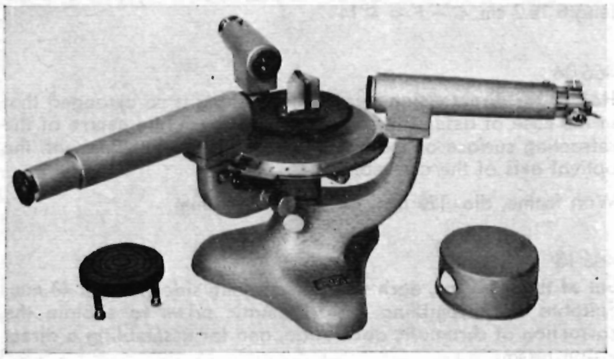
Complete with the following parts:

Telescope with objective, 20 mm aperture, 160 mm focal length, and eyepiece with cross-hairs; the telescope can be turned and locked in any desired position. When locked, fine adjustment by micrometer screw is still possible,

Prism table and graduated circle, which can be turned and locked together, with degree scale and vernier reading to $^1/_{10}$°,
Grating holder for inserting the simple line grating, n = 1,000/cm (471 51),

Collimator tube, permanently fixed to the support, telescopic, with slit variable by a micrometer device,

on solid stand of pleasing shape, overall height approx. 22 cm.



467 21

467 21

Spectrometer and goniometer with spectroscope attachment. Same as for 467 20, but with a wider range of application due to additionally provided parts. Without prism it may be used for the above determinations on prisms and gratings. With prism fitted in position or with simple line grating (471 51) it may be used as a spectroscope to observe and measure spectra. Additionally provided parts not included in 467 20:

Flint glass prism, length of base: 30 mm; $\vartheta = n_F - n_C$, 0.017, permanently mounted on a prism table, swivelling reference prism in front of the micrometer slit, by which light from a laterally arranged source may be dispersed into a spectrum and brought into the field of vision for comparison,

Scale tube, scale appears within field of vision when illuminated, can be used to determine wavelengths with the help of known spectral lines.

467 64
Spectral tubes, for observing line or band spectra; in the classical form of the spectral tube with narrow capillary tube and metal electrodes in the enlarged ends, which often renders a slit superfluous; overall length approx. 22 cm.

For mounting in holder (467 81).

Recommended sources of high tension for operation:

Induction coil 521 02
or
High-tension power supply 522 37

Gas filling	N_2	O_2	H_2	He	Ar	Ne
Cat. No.	467 64	467 65	467 66	467 67	467 68	467 69

467 81
Holder for spectral tubes, for convenient arrangement of the spectral tubes and supply of high tension. The tubes are held from above by means of a sprung clip, which also supplies them with current.

With 4 mm socket and rod for clamping; without stands.

467 82 (not shown)
Neophane glass plate, for demonstrating absorption in certain spectral regions by a solid; in the case of neophane glass, the absorption bands almost resemble lines on account of its rare earth content. For this reason the plate is also suitable for observing higher order interference bands.

467 95 (not shown)
Set of 3 coloured glass plates, for introductory experiments on dispersion and spectra; red, green, blue, each one 50×50 mm² in size.

468 21 (not shown)
Set of 3 dark red-green filters, for demonstrating subtractive colour mixing; consists of three coloured glass plates, 50×50 mm² in size, of the same quality: 6.5% transmission for green light in the wavelength region from 480 to 560 nm and 80% transmission for red light above a wavelength of approx. 680 nm.

Therefore, white light passing through one filter appears green, through two filters red-green and through three filters red.

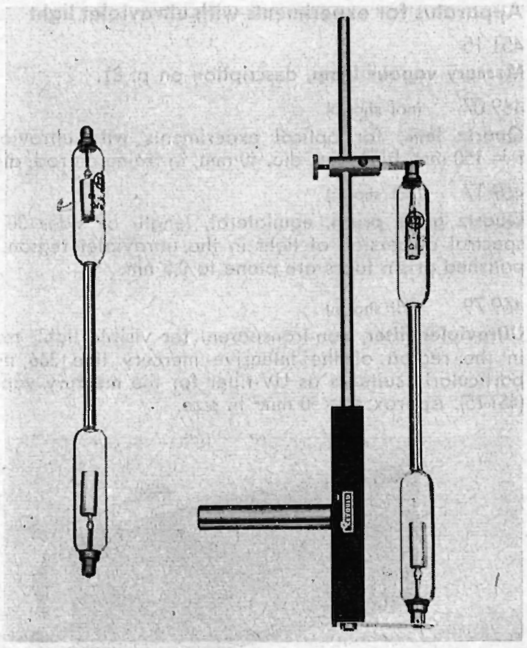
467 31 (not shown)
Platinum wire for colouring flames. One end of the wire is bent to form an eye, the other end is sealed into a glass tube by which it is held. The wire is approx. 30 mm long, 0.5 mm thick, complete with rubber stopper and test tube for storage.

467 32 (not shown)
Set of 10 magnesia rods, for colouring flames.

467 41 (not shown)
Set of 10 salts for colouring flames, for spetroscope observations. The salts of the metals Na, K, Li, Ba, Sr, Ca, Rb, Cs, Cu, and In are supplied in glass containers with screw caps, which are clearly displayed in a wooden holder.

469 82 (not shown)
Card with phosphors, 10 samples of technically used phosphors, each 25×40 mm² in size; exhibiting fluorescence and phosphorescence with various emission colours; pasted on cardboard, 10×14 cm².

469 74 (not shown)
Fluoresceine-sodium, its aqueous solution is strongly fluorescent, approx. 50 g, in bottle.



467 64/69 PH 2035

Fig. 50 Spectral tube (467 67) mounted in holder (467 81)

468 01 – 13 (not shown)
Monochromatic light filters, 50×50 mm², in frame, covering the following spectral regions:

Colour	Transmission in nm*)	Cat. No.
dark red	> 640	468 01
red	> 608	468 03
yellow	550–590	468 05
yellow-green	515–575	468 07
blue-green	490–555	468 09
blue with violet	< 485	468 11
violet	< 465	468 13

Monochromatic light filters being somewhat sensitive to heat, we recommend arranging them behind the condenser in the optical arrangement.

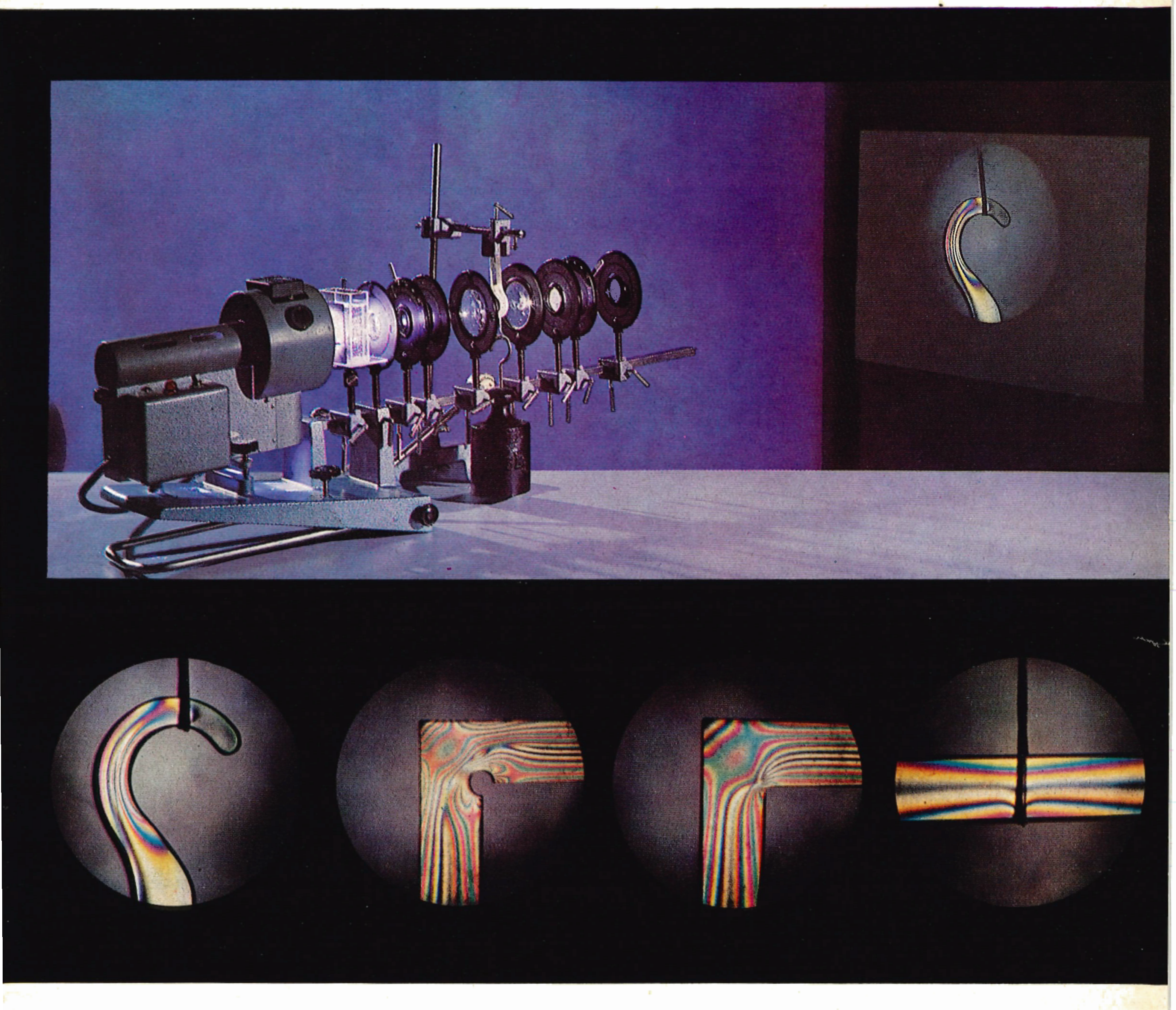
*) 1 nm (nanometre) = 1 mμ = 10^{-9} m

468 30 – 33 (not shown)
Light filters, for filtering out the visible lines of the mercury spectrum, 50×50 mm² in size, mounted in frame:

Colour	Transmission in nm	Cat. No.
yellow	578	468 30
green	546	468 31
blue	436	468 32
violet	405	468 33

468 74 (not shown)
Infrared filter, made of black glass which becomes transmissive in the infrared region, 50×50 mm² in size.

469 79 (not shown)
Ultraviolet filter, for description see p. 96.



Transparent models made of highly photoelastic polyester resin are elastically deformed and observed in circulary polarised light. The lines of equal mechanical stress, the so-called isochromatics, are rendered visible in projection by means of the double refraction produced.

Apparatus for experiments with ultraviolet light

451 15

Mercury vapour lamp, description on p. 81.

469 07 (not shown)

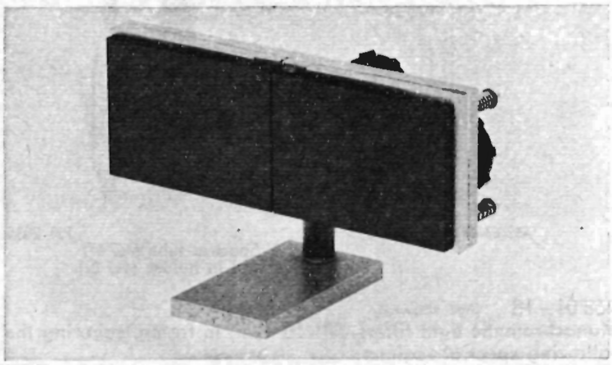
Quartz lens, for optical experiments with ultraviolet light, f = 150 mm, biconvex, dia. 40 mm, in frame on rod, dia. 10 mm.

469 17 (not shown)

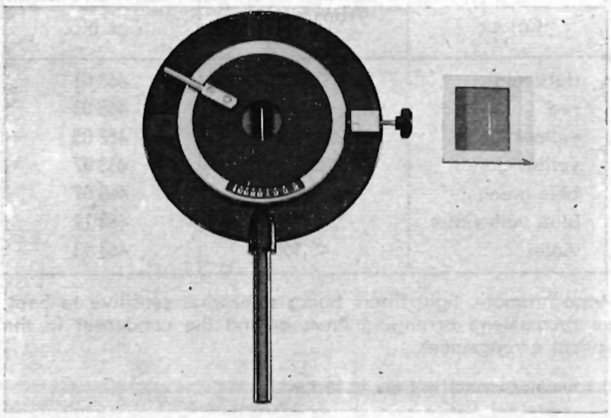
Quartz glass prism, equilateral, length of sides 30 mm; for spectral dispersion of light in the ultraviolet region. The two polished prism faces are plane to 0.5 nm.

469 79 (not shown)

Ultraviolet filter, non-transparent for visible light, transparent in the region of the intensive mercury line 366 nm, hence particularly suitable as UV-filter for the mercury vapour lamp (451 15). Approx. 50×50 mm² in size.



471 05



460 14 471 06

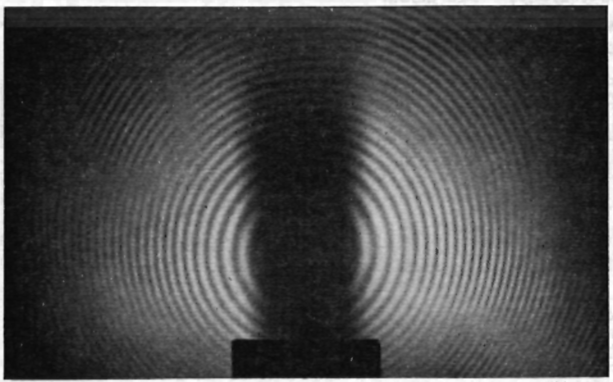


Fig. 51 PH 2036

A photograph of the projected image obtained in the interference experiment with the mica plate (471 07). The image is several metres in size.

468 72 (not shown)

Zinc sulphide screen, for demonstrating the ultraviolet spectrum. The screen exhibits vivid fluorescence and phosphorescence; subsequent irradiation with infrared light, e.g. using the filter 468 74, will quench the phosphorescence of the irradiated parts.
On plastic sheet, approx. 15×10 cm² in size.

469 42 (not shown)

Ultraviolet phosphorescent screen, for demonstrating ultraviolet light if the use of photographic material takes up too much time.
White plastic sheet, approx. 14×10 cm² in size, one half covered with luminous paint.

476 71 (not shown)

Fluorescent glass plate, for tracing beams of light, especially in the ultraviolet region; dia. approx. 12 cm, in frame on rod, dia. 10 mm.

471 05

Fresnel's mirror, for demonstrating the interference of light after reflection by two mirrors. This classical experiment is supposed to be difficult to perform; but with the equipment here described, and the instructions supplied with it, it will easily, reliably and impressively succeed.

The two mirrors are mounted on a common base plate and have been rendered parallel with great care. One of the two mirrors is rigidly mounted, the other one can be turned with a milled head screw; its angular position vis-a-vis the other mirror can be slightly altered.

Mirrors made of black, polished glass plates, each 50×70 mm² in size, on metal frame; complete with base for mounting on the optical bench.

Additionally recommended pieces of equipment:

1 Small optical bench	460 41
1 Illuminating device	450 60/51/460 17
1 Prism table	460 25
1 Adjustable slit	460 14

(See: "LEYBOLD Physics Leaflets", DC 535.412; b and c)

460 14

Adjustable slit, both edges displaceable, suitable for all experiments in diffraction and interference, and all spectrum experiments. A fact that renders adjustment particularly convenient: the slit can be rotated within the frame and locked in any desired position with a knurled-head screw.

Height of slit 20 mm; opening lever with scale graduated from 0 to 1.6 mm; in frame, dia. 120 mm, on rod, dia. 10 mm.

471 06

Double slit for Young's interference experiment. This experiment is easily comprehensible and very suitable for quantitative evaluation. The double slit is mounted in a frame, 50×50 mm² in size, and should be inserted into holder (460 22).

471 07

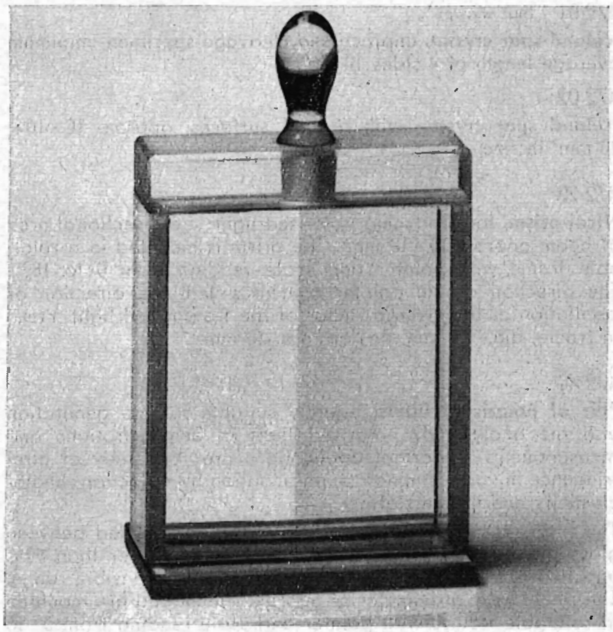
Mica plate for the interference experiment according to Professor Pohl, for observation of the interference rings produced by light that is reflected at the front and rear side of a mica sheet. This interference experiment does not require any adjustment and can be demonstrated to large audiences.

If the mica sheet is illuminated with a spectrum lamp, the interference rings can be displayed on a screen everywhere within the reflected beam of light.

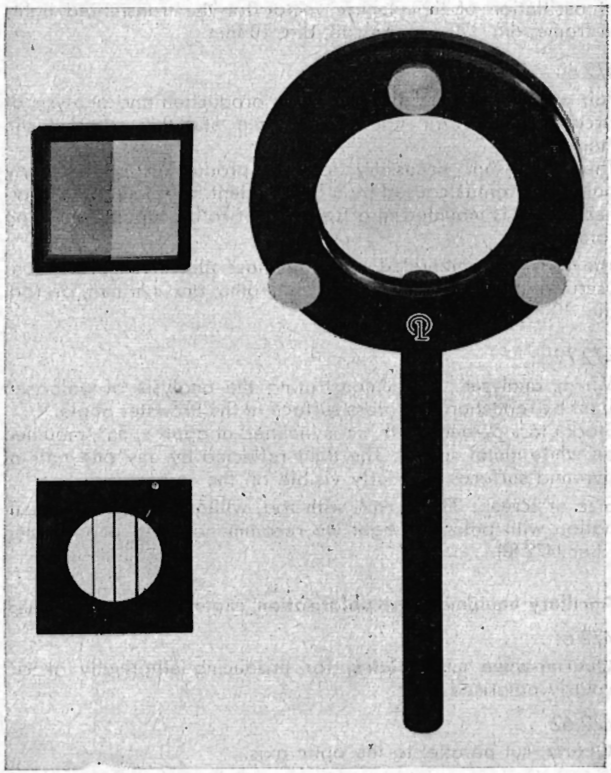
The mica plate is of selected quality, approx. 15×11 cm² in size (irregular shape).

Most suitable for illumination is the mercury vapour lamp (451 15).

(See: "LEYBOLD Physics Leaflets", DC 535.412; e)

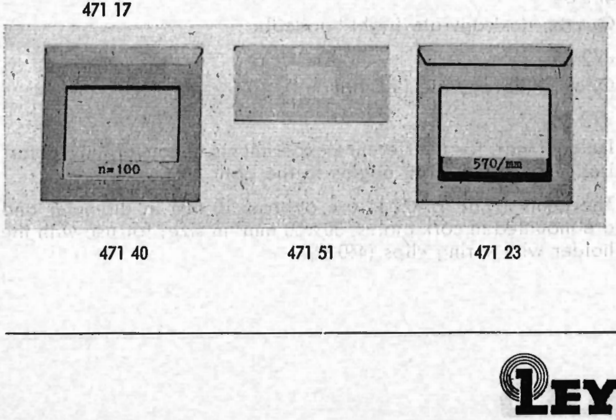


471 10



471 12
471 17

471 11



471 40 471 51 471 23

471 10

Interference prism according to Winkelmann-Abbe, for demonstrating the interference of light after refraction at a double prism. This experiment is convenient to adjust and gives rise to very brilliant interference patterns which may be observed even in moderately darkened rooms.

The biprism is provided at the inner surface of a glass cell and has prism angles of approx. 8°. By filling the glass cell with a mixture of benzene and benzol (1:9) the deviation is so much reduced that on the passage of light through the cell two beams are formed which seem to originate from two closely neighbouring virtual sources of light and give rise to interference lines by superposition.

Glass cell, made of plate glass, approx. 60 mm high; one wall forming a biprism, with ground stopper on the opening for pouring in liquid, and protruding base plate, unfilled.

Additionally recommended items:

1 Small optical bench	460 41
1 Illuminating device	450 60/51
1 Single-lens condenser with aperture attachment	460 17
1 Adjustable slit	460 14
1 Prism table	460 25

(See: "LEYBOLD Physics Leaflets", DC 535.412; d)

471 11

Glass plates for Newton's rings, for interference experiments with individual observation or projection.

Consists of a plane glass plate and a plano-convex lens, dia. 40 mm, which can be pressed against one another between metal rings by means of three screws. The interference pattern then formed can be observed on the surface of the plano-convex lens. On rod, dia. 10 mm.

471 12

Partly bloomed glass plate, plate-glass plate, 50×50 mm² in size, one half coated with an antireflection coating, to explain the technically important coating of photographic objectives. The coated half appears brighter in transmitted light and darker in reflected light than the untreated part of the surface.

471 17

Aperture with three diffraction wires, metal frame, 50×50 mm² in size, with three wires of 0.2, 0.5, and 0.8 mm diameter, respectively, extended across its circular aperture. The attachment should be mounted in holder (460 22).

471 23

Copy of a Rowland grating, with approx. 5,700 lines per cm. Copy of grating on transparent foil, 25×35 mm², mounted between two glass plates. The glass plates are mounted in a metal frame, 50×50 mm² in size, which should be inserted into holder (460 22).

471 40

Wire-mesh grating, metal wire gauze with 100 wires per cm, in metal frame, 50×50 mm², for insertion into holder (460 22).

471 51

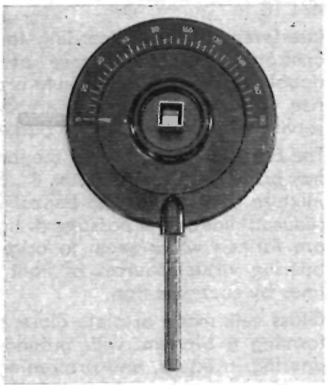
Simple line grating, high-grade line grating for demonstrations with the optical bench and for spectroscopy experiments, e.g. using spectrometers (467 20 and 467 21). The resolving power permits second-order separation of the Na-D-line.

Metal line grating on plate-glass plate: grating constant 10 µm, line thickness 6 µm, grating area: 15×10 mm² (lines are 10 mm long), size of plate-glass plate: 50×27 mm², 3 mm thick. The border surrounding the grating is metallised, therefore non-transparent to light. The metallisation does not wipe or scratch off and will resist most of the more corrosive chemical reagents.

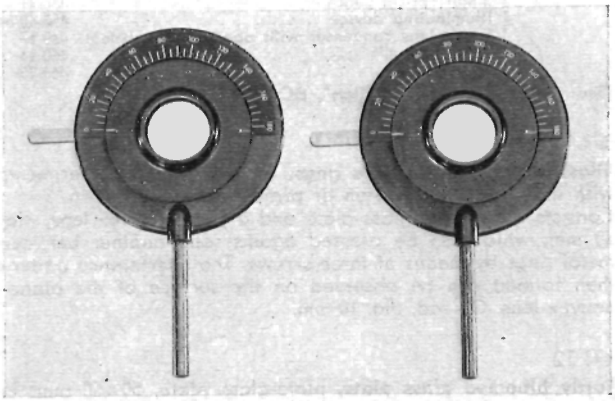
For demonstrations with the optical bench, the grating should be inserted into the holder with spring clips (460 22). The spectrometers (467 20 and 467 21) are provided with devices for holding this grating.

nach Köln
n die

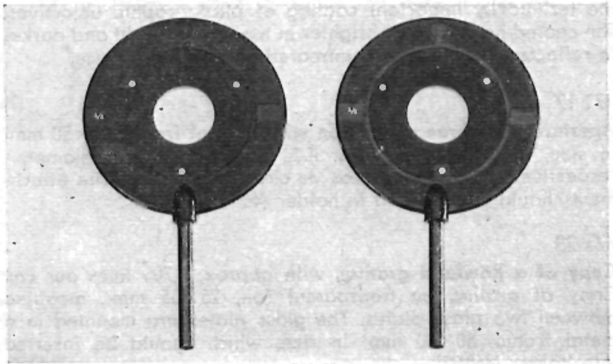
472 02



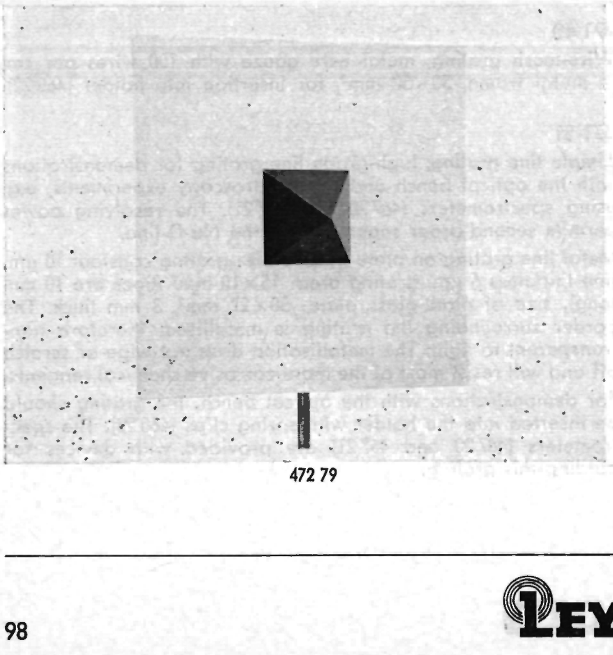
472 23



472 40



472 60



472 79

472 01 (not shown)

Iceland spar crystal, unprocessed cleavage specimen, minimum average length of 4 sides 10 cm.

472 02

Iceland spar crystal, with ground surfaces, approx. 10×10×20 mm³ in size.

472 23

Nicol prism, for producing polarised light; cross-sectional area of beam approx. 10×10 mm². The prism is mounted in a rotatable frame with pointer and scale reading from 0 to 180°. The direction of the pointer coincides with the direction of oscillation of the electric vector of the transmitted light. Prism in frame, dia. 120 mm, on rod, dia. 10 mm.

472 40

Pair of polarising filters, equally suitable for the generation and the analysis of polarised light in demonstrations and measurements. Important applications are: the study of birefringence in various minerals, polarisation by reflection, photoelasticity and the Kerr effect.

The filters consist of dichroic plastic foils embedded between glass plates. The degree of polarisation is greater than 99% and is nearly independent of wavelength in the visible range. The filters have a diameter of approx. 40 mm and are mounted in rotatable frames with pointer and scale reading from 0° to 180°. The direction of the pointer coincides with the direction of oscillation of the electric vector for the transmitted light; in frame, dia. 120 mm, on rod, dia. 10 mm.

472 60

Pair of quarter-wave plates, for the production and analysis of circularly polarised light, e.g. when studying photoelastic models.

The phase-shift necessary for the production of circularly polarised light is caused by a birefringent foil of suitable thickness which is mounted in a frame so as to be capable of being rotated.

The foils are embedded between glass plates for protection; useful diameter approx. 40 mm, in frame, dia. 120 mm, on rod, dia. 10 mm.

472 79

Mirror analyser, for demonstrating the analysis of polarised light by reflection at a glass surface at the Brewster angle.

Black glass pyramid with sides inclined at approx. 56°, mounted on white metal screen. The light reflected by any one pair of pyramid surfaces is clearly visible on the screen.

Size of screen: 30×30 cm², with rod, without stand. For illumination with polarised light we recommend using a polarising filter (472 40).

Ancillary equipment for polarisation experiments(not illustrated)

472 61

Quarter-wave mica plates, for producing elliptically or circularly polarised light.

472 62

Quartz, cut parallel to the optic axis.

472 64

Quartz, dextrogyrate (right-handed).

472 65

Quartz, laevogyrate (left-handed).

472 66

Iceland spar, for interference experiments in convergent, polarised light, cut at right angles to the optic axis.

The items 472 61 to 472 66 are approx. 10 mm in diameter and are mounted in cork plates, 50×50 mm² in size; for use with the holder with spring clips (460 22).

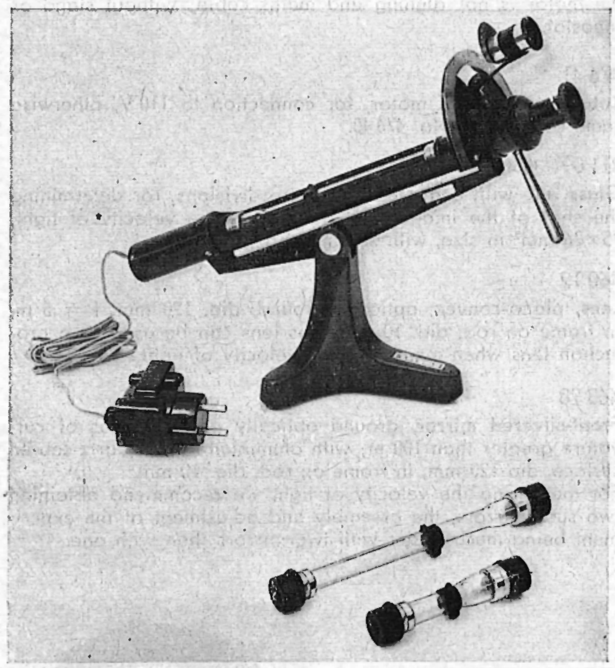
471 61 (not shown)

Rapidly cooled glass, for demonstrating the internal stresses by means of polarised light; approx. 20×20 mm², 10 mm thick.

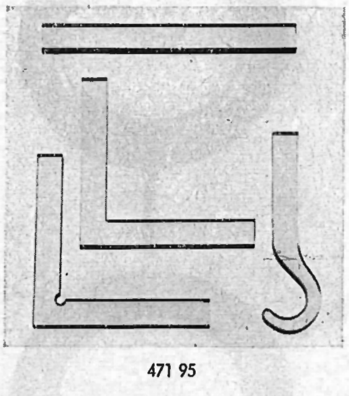
471 92 (not shown)

Securit glass plate. "Securit" is the trade name of a security glass with great internal stresses produced by thermal pretreatment, which will, therefore, crumble into dust without the formation of splinters if its surface is damaged. The internal stresses of this glass can be seen in polarised light.

They may be observed by individual experiments with the polarising filters (472 40) or also in reflected daylight.



472 83/84 472 85



471 95

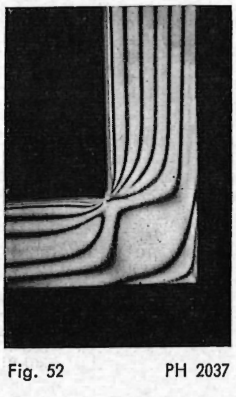
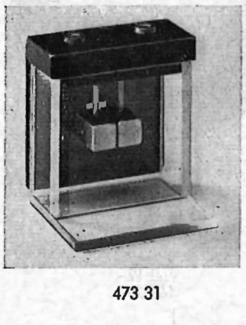
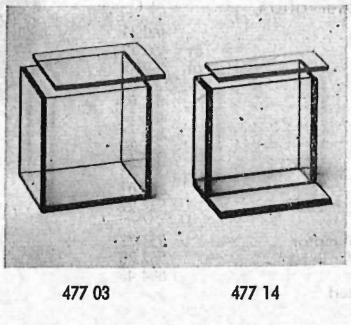


Fig. 52 PH 2037



473 31



477 03 477 14

472 83

Mitcherlich's polarimeter, for connection to 220 V; for determining the optical rotation of liquid substances; the use of observation tubes of different lengths is possible. The apparatus is supplied complete with one 200 mm long tube. The opening that receives the tube can be closed with a rotatable opaque cover.

The polarimeter features the following parts:

polariser and rotatable analyser. The test field is between the specimen and the eye, so that even somewhat turbid substances can be measured with ease. Graduated circle with 0° to ± 90° graduation, divided in whole degrees; with vernier reading to 0.1°, and reading magnifier.

Permanently set semishadow device with a semishadow angle of 9°; plug-in lamp, 6 V, 2.4 W, with transformer provided within the supply leads.

Observation eyepiece with 3-fold magnification.

The apparatus is mounted on a solid base and can be tilted about its transverse axis.

472 84

Mitcherlich's polarimeter, for connection to 110 V; otherwise same as for Cat. No. 472 83.

472 85

2 Tubes for the polarimeter (472 83/84), for direct per cent. reading of dextrose concentrations. Length: 190.09 mm (1° ≡ 1%) and 95.04 mm (1° ≡ 0.5%).

471 95 (cf. Plate VII)

Set of photoelastic models, for observing the birefringence caused by mechanical stresses in the elastic deformation of transparent substances. In technology this property is much used to study the static loads on building components.

The models are made of photoelastically highly sensitive polyester resins which have been freed of internal strains by careful thermal treatment. The set consists of a bending rod (approx. 15 cm long), one right angle with sharp-edged and one with cut-away inner bend (length of sides approx. 10 cm) and the model of a crane hook. The models are best viewed in circularly polarised light which can be produced with the pair of polarising filters (472 40) and the pair of quarter-wave plates (472 60).

473 31

Kerr cell, for observation of the birefringence of a dielectric polarised in an electric field (known as "Kerr effect").

The electrodes are spaced 1 mm apart. They are mounted in an insulating bar and provided with 4 mm connecting sockets. Complete with plate-glass box, 50×50×20 mm³, and diaphragm with aperture; unfilled.

As dielectric we recommend nitrobenzene (473 32).

473 32

Nitrobenzene, chemically pure, for potential measurements and Kerr effect; bottle holding 100 g.

Fig. 52 Strained right angle. Isochromatic exposure taken in the light of a sodium spectrum lamp (see also Plate VII).

477 03/13/14/19/20/25/26

Plate glass cells, for optical measurements such as absorption and extinction and for the projection of processes in liquids. Made of nearly colourless plate glass and sealed with low melting point glass. Withstand all liquids except acids that will attack the glass itself, such as hydrofluoric acid.

Cat. No.	477 03	477 13	477 14*	477 19	477 20*	477 25*	477 26*
Height mm	50	80	50	100	100	100	100
Width mm	50	60	50	100	100	80	60
Depth mm	50	10	20	10	10	25	20
Wall thickness mm	2–2.5	2.5–3.5	2.5–3.5	2.5–3.5	2.5–3	2.5–3	2.5–3

* With projecting base plate

The measurement of the velocity of light

The measurement of the velocity of light has only recently been included in the physics curriculum, in spite of the great importance of this natural constant. The reason was the great difficulty of procuring the necessary apparatus. But now that electric motors for speeds of approx. 30,000 r.p.m. have become commercially available, the manufacture of sufficiently fast-rotating mirrors has become easier. The measurement can now be performed with comparatively simple apparatus.

The arrangement according to Foucault and Michelson suggested by us does not make exaggerated demands on the understanding of the pupils, as the measurement of the transit time of the light pulses is done in comparatively easy steps. The number of revolutions of the rotary mirror can be brought to very exactly 440 r.p.s. by comparison of the noise of the motor with a 440 c/s tuning fork, as the clearly heard beats facilitate tuning. But the light pulses emitted by the rotary mirror can also be transformed into electric pulses by means of a photocell and counted with the demonstration scaler (559 62) or compared with a known frequency by means of the school cathode ray oscilloscope (575 15).

The space required for the measurement is surprisingly small in the case of the suggested arrangement (only approx. 8 m). The optical components must be of high quality: projection lens and mirror must be optically ground and sufficiently large. The apparatus listed below has been carefully selected in the light of these considerations. By careful work results that are correct to 5% can easily be attained.

A detailed description of the entire measurement and its evaluation will be found in "LEYBOLD Physics Leaflets", DC 535.222; b.

476 40

Rotary mirror with motor, for connection to 220 V, for speeds of up to 28,000 r.p.m., for determining the velocity of light.

The mirror is 10×20 mm² in size, both sides optically ground, metallised, and covered with a quartz layer. The motor is housed in a cylindrical plastic case ending in a metal cap with airing vents on top. The motor axle protrudes on top and carries the mirror in a fork. The mirror is protected by a small casing, open in front. The motor speed can be varied by means of a series resistor.

Overall length approx. 18.5 cm, with holder for mounting on 12 mm stand rods, switch, key for adjusting the mirror when the motor is not running and mains cable; without stand or rheostat.

476 41

Rotary mirror with motor, for connection to 110 V, otherwise same as for Cat. No. 476 40.

311 09 (not shown)

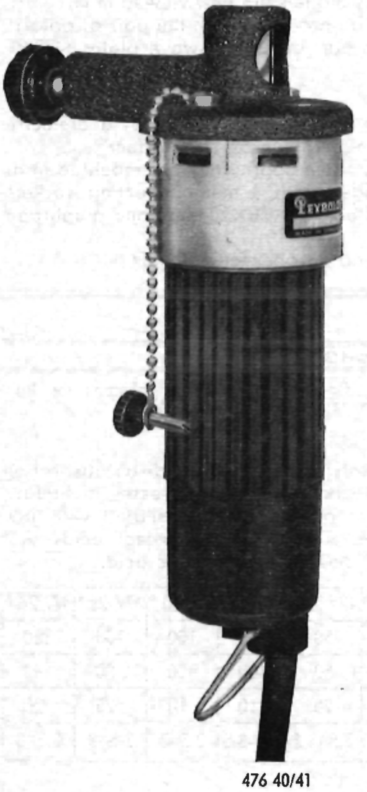
Glass rule with engraved millimetre divisions, for determining the shift of the image when measuring the velocity of light, 75×26 mm² in size, with 50 mm long graduation.

460 12

Lens, plano-convex, optically ground, dia. 120 mm, f = 5 m, in frame on rod, dia. 10 mm. This lens can be used as a projection lens when measuring the velocity of light.

463 20

Front-silvered mirror, ground optically plane, radius of curvature greater than 100 m; with aluminium- and quartz-coated surface, dia 120 mm, in frame on rod, dia. 10 mm.
For measuring the velocity of light we recommend obtaining two such mirrors, the assembly and adjustment of the experiment being much easier with two mirrors than with one.



476 40/41

We recommend the following pieces of equipment for measuring the velocity of light by means of individual observations.

I. Special apparatus

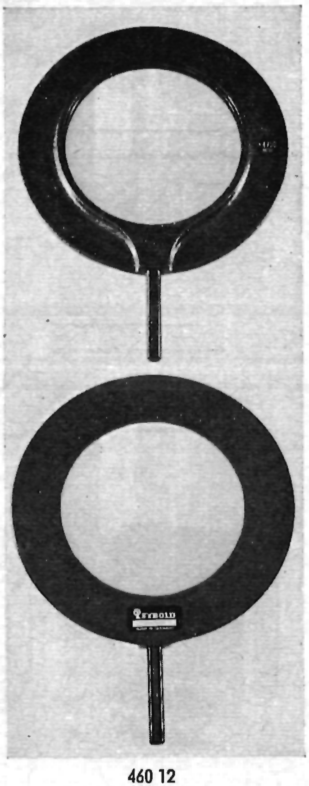
1 Rotary mirror with motor	476 40/41
2 Front-silvered mirrors	463 20
1 Lens, f = 5 m	460 12
1 Glass rule	311 09
1 Glass plate (object plate)	

II. Stands for arranging the special equipment:

3 Stand bases	300 01
3 Sets of levelling screws	300 06
1 Bench clamp	301 06
1 Stand rod, 50 cm long	300 42
3 Stand rods, 25 cm long	300 41
3 Leybold bosses	301 01

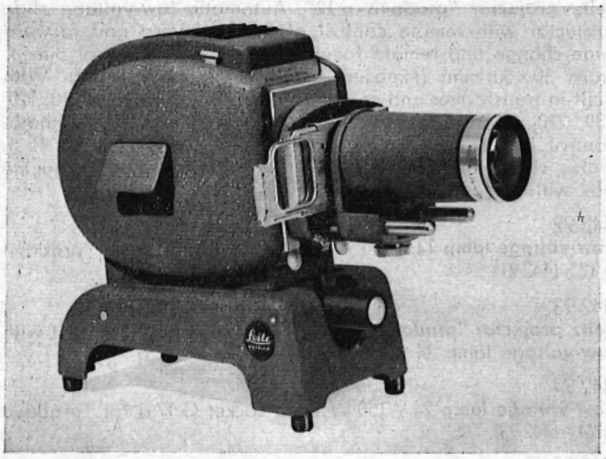
III. For illumination and observation

1 Optical bench	460 41 or 460 42 or 460 43
1 Lamp-house with lamp	450 60/51
2 Lenses, f = 100 mm	460 03
1 Adjustable slit	460 14
2 Holders with spring clips	460 22
1 Iris diaphragm	460 26
1 Stand rod, 50 cm long	300 42
8 Leybold bosses	301 01
1 Rheostat, 1,000 Ω for 220 V motor or 1 Rheostat, 320 Ω, for 110 V motor	537 22 537 23
1 Transformer, 2–12 V, 100 W	562 75
2 Cut-out switches	504 45
Connecting leads as required	



460 12
463 20

Leitz-projectors PRADO and "pradovit"



442 50/51

In the preface of his paper: "The Leitz lantern slide projector PRADO 250/500 in natural science teaching" Professor Dr. L. Bergmann writes inter alia:

> In the teaching of physics and chemistry there are a large number of experiments which are difficult to demonstrate to a larger audience without using special appliances, either because the apparatus used for them is too small and cannot be recognised clearly from a distance, or because the phenomena to be demonstrated take place in a horizontal plane and are, therefore, difficult to watch. The first group includes the demonstration of electric measuring instruments in operation, whereas the second group comprises, for example, the demonstration of electric and magnetic lines of force and all processes that take place on liquid surfaces. In the following we shall show by means of a number of examples that the lantern slide projector PRADO 250/500 is particularly suitable for powerful projection of physical experiments if suitable accessories are used. This opens up new avenues for demonstrations in schools."

For this Leitz projector Professor Bergmann himself devised a number of elegant experiments which we have extended by our own developments. According to an agreement with Messrs. Ernst Leitz GmbH, Wetzlar, we have taken over the manufacture of the accessories required and hope to create further means for impressive and above all time-saving experiments in this manner.

442 50

Leitz projector PRADO 250 for 250 W lamps. The apparatus is supplied by us in a design which differs from the standard design and leaves the necessary space between condenser and objective lens for the insertion of more extended objects to be demonstrated in projection. The projector in this design consists of the following parts (cf. Fig. 53):

Casing ① with lamp holder, aspherical lens and heat filter; variable height, takes interchangeable attachments in front.

Attachment ② with two rods, rotatable, supports interchangeable condenser, holder and objective lens.

Interchangeable condenser ③. Two condensers are supplied which are marked "85–120 mm" for projecting flat objects and "200–300 mm" for projecting extended objects.

Holder ④ for mounting the slide holder, the base plates or a measuring instrument.

Objective ⑤, type HEKTOR 1:2.5, f = 120 mm, coated, with support ⑦ and tube ⑥ for mounting the objective, with lid. The objective lens was so chosen that images of adequate size will be formed at a distance of 2–3 m (distance between demonstration bench and blackboard) and that sufficient working space remains between condenser and objective lens.

The apparatus is supplied complete with one large slide changer for slides, 50×50 mm^2 in size, but **without lamp.**

442 51

Leitz projector PRADO 500 for lamps up to 500 W, same design as for Cat. No. 442 50 but with built-in cooling blower, 220/110 V A.C., switchable; **without lamp.**

Lamps to Leitz projector PRADO 250/500, with socket P 28.

442 52
Lamp, 250 W; 220 V

442 53
Lamp, 250 W; 110 V

442 54
Lamp, 500 W; 220 V

442 55
Lamp, 500 W; 110 V

442 59 (not shown)

Additional heat filter, for slide projection with the Leitz projector PRADO 500 (442 51) when using the 500 W lamps, 220 or 110 V (442 54/55).

442 56 (not shown)

Transport case, vulcanised fibre, for Leitz projector PRADO 250 or 500.

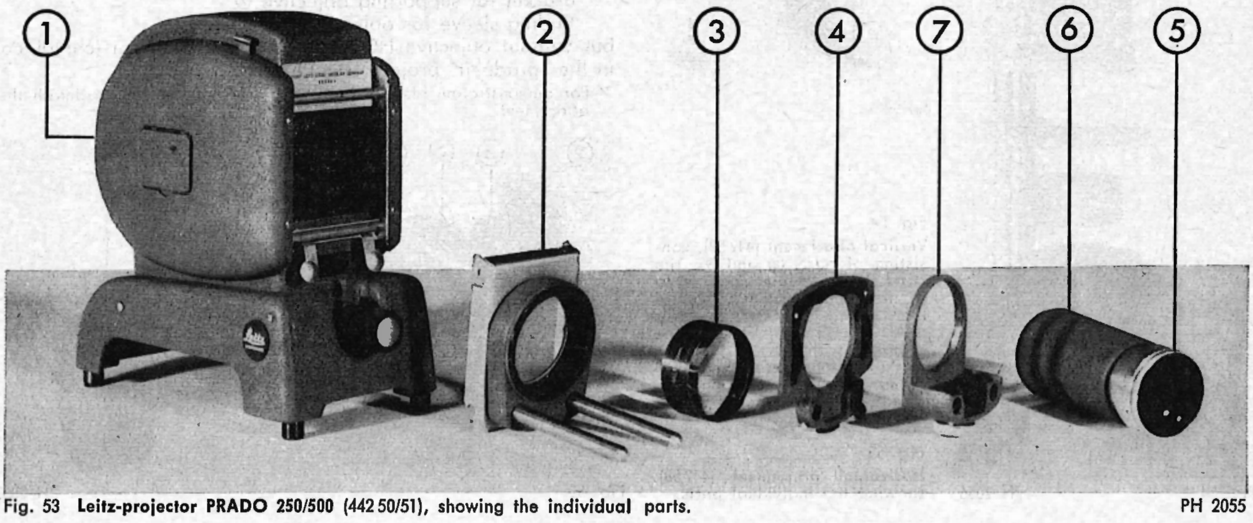
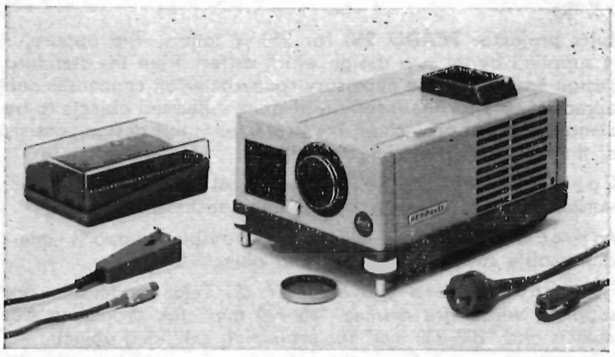


Fig. 53 **Leitz-projector PRADO 250/500 (442 50/51), showing the individual parts.** PH 2055



442 91/93

Leitz projector "pradovit"

In addition to the projectors PRADO 250 and 500, we have now also included two low-voltage projectors in our programme. These are the more recent Leitz developments "pradovit n 12" and – for larger audiences – "pradovit n 24". When considering whether, for a given purpose, a PRADO or a "pradovit" projector would be more suitable, the following points should be noted. If the projector is to be used for experiments only, then a PRADO projector offers advantages. If, however, the projector is to be used both for experimenting and for slide projection – e.g. for projecting series of slides – then the "pradovit" projector can be recommended because of its automatic slide changer and the provision for remote control. In the case of a low-voltage projector the heating-up and the temperature of the aperture window are naturally lower.

Whereas we supply the PRADO projector with horizontal attachment, this accessory is not included with the "pradovit" projector and must be ordered separately under Cat. No. 442 58. It can be mounted on the "pradovit" projector using the holder for attachments (442 95).

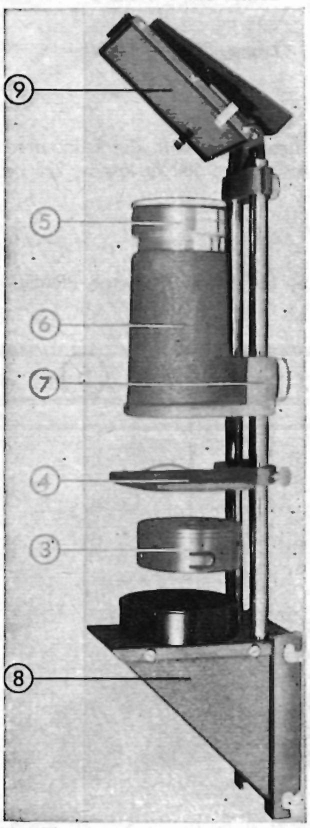
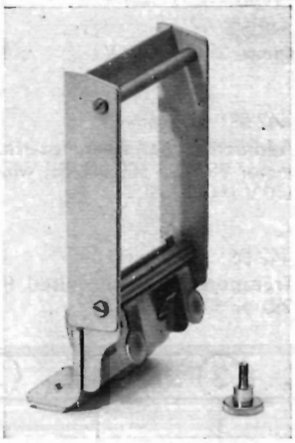


Fig. 54 PH 2056



442 95

Fig. 54
Vertical attachment (442 57), consisting of parts ⑧ and ⑨. The parts shown in faint print, ③ to ⑦, form part of the horizontal attachment. The Leitz projector PRADO (442 50/51) is supplied complete with this; in the case of the Leitz projector "pradovit" it can be ordered separately (442 58). Cf. Figs. 53 and 55.

Fig. 55
Horizontal attachment (442 58), showing the individual parts.

442 91
Leitz projector "pradovit n 12". Automatic low-voltage slide projector with remote control of the backward and forward slide change and remote focussing for slides, external dimensions 50×50 mm² (exposure sizes up to 40×40 mm²). With built-in transformer and cooling blower, switchable for 110, 120, 130, 220, 230, 240 V–50 to 60 c/s and with 4 m long remote-control cable, low-voltage lamp 12 V/100 W (socket Ba 15 s), mains cable, objective HEKTOR 1:2.5/120 mm and magazine box with 2 magazines for 30 slides each.

442 92
Low-voltage lamp 12 V/100 W, with socket Ba 15 s, for "pradovit n 12" (442 91).

442 93
Leitz projector "pradovit n 24", same design as 442 91, but with low-voltage lamp 24 V/150 W, with socket G 17 q.

442 94
Low-voltage lamp 24 V/150 W, with socket G 17 q for "pradovit n 24" (442 93).

442 95
Holder for attachments. With the use of this part the projectors "pradovit n 12" and "pradovit n 24" (442 91, 442 93) can be turned into demonstration projectors.

442 57
Vertical attachment for Leitz-projectors PRADO 250 and 500 and "pradovit n 12" and "n 24". This attachment is needed for many of the experiments now described, because it permits the objects to be projected to be arranged on a horizontal base plate. The use of the attachment does not present any difficulties if the PRADO is ordered as suggested by us (442 50/51) or the "pradovit" projector (442 91/93) is ordered together with the holder for attachments (442 95) and the horizontal attachment (442 58); otherwise it may be necessary to obtain individual parts separately.

The attachment consists of two parts (cf. Fig. 54):

1) Attachment ⑧ with mirror case and rods, which is inserted instead of attachment ② and deviates the light and carries the other parts.
2) Swivelling mirror ⑨, highly polished front-silvered mirror in metal frame with protective lid, for fitting on the rods of the attachment. The mirror deviates the beam of light towards a vertical projection screen.

442 58
Horizontal attachment, for turning the projectors "pradovit n 12" and "pradovit n 24" into demonstration projectors, consisting of (cf. Fig. 55):

Attachment with aperture and rods ②
2 Interchangeable condensers 85–120 mm and 200–300 mm ③
Holder with slide changer*) ④
Bracket for supporting objective ⑦
Sliding sleeve for objective lens ⑥

but without objective HEKTOR 1:2.5, f = 120 mm (contained in the "pradovit" projectors n 12 and n 24).

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*) For demonstration of individual slides, without having to detach the attachment.

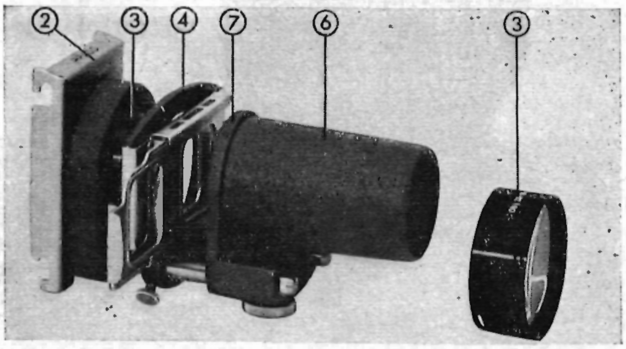
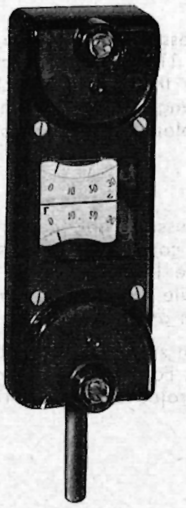
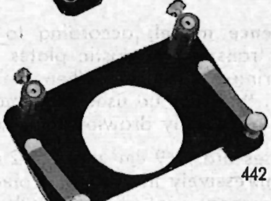


Fig. 55 PH 2057



442 73

442 60



442 61

442 72

442 73

Twin moving-coil instrument; zero point in the left half, suitable for projection. Moving-coil instrument with two independent movements; scale can be projected with Leitz projectors PRADO and "pradovit". With this arrangement two electric parameters can be projected simultaneously in an undarkened room and thus be rendered visible to a large audience. Projection to a blackboard has also been found useful, because in this case the values read can be plotted or otherwise noted down directly beside the projected image. Sensitivity of movement: 10 μA (2 mV) per scale division; full deflection at 300 μA (60 mV).

Range control boxes, which are supplied separately, give 24 measuring ranges per movement (see Fig. 56).

In case, 16×6×5 cm³, with rails for fastening on Leitz projectors and stand rod for mounting on stand base, optical bench, etc.

2 coaxial cables, each 2 m long, are supplied with the instrument, which is supplied without range control boxes (442 47). We recommend to purchase two of the latter.

442 60

Base plate, for vertical or horizontal projection of objects of all kinds, approx. 11×7 cm² in size, with 50 mm dia. circular aperture, recessed to take plates of 50 mm diameter and spring clips to retain larger objects.

The rails on the under side are for fitting on the Leitz projectors PRADO, "pradovit", or on the support for base plates (442 90) in the case of an optical bench assembly.

442 61

Base plate with connecting sockets, for vertical and horizontal projection of experiments that require the supply of an external electric voltage.

Same as Cat. No. 442 60, but with 2 insulated connecting sockets to take 4 mm banana plugs and vertical bores, dia. 2 mm, with set-screws for inserting bare wires.

442 72

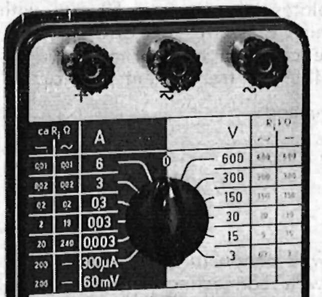
Bracket, for arranging larger objects in the object plane of the Leitz projectors PRADO or "pradovit"; with guide slots and clamping screw for fitting on the rods of attachment ② and a hole for inserting the prism table (460 25) on which any object may be set up and fastened.

442 74

Range control box, for the twin moving-coil instrument (442 73), with 24 current and voltage measuring ranges which can be selected by simply turning a range-control switch on a clearly laid-out scale. Moreover, the box is provided with a D.C.-A.C. switch enabling all these ranges to be used either for D.C. or for A.C. The ranges are so selected that almost any current or voltage value likely to occur in practical classroom work can be covered (6 A to 0.003 A, 500 V to 3 V, each range for both A.C. and D.C.). The connecting cables for the twin moving-coil instrument are approx. 2 m long; this allows of great freedom for the arrangement of the projector and leaves sufficient room for assembling the experiments.

We recommend purchasing two of these range-control boxes because the twin moving-coil instrument has two entirely independent movements. For details of these instruments see p. 121.

442 83
Twin moving-coil instrument; zero point at the centre
442 84
Range control box for 442 83
For descriptions and illustrations, please see appendix, p. 206.



442 74

Fig. 56

Twin moving-coil instrument (442 73) in projection arrangement using Leitz-projector PRADO (442 50/51). The two movements of the twin moving-coil instrument are each connected with one range control box; top left: projected image of the two scales.

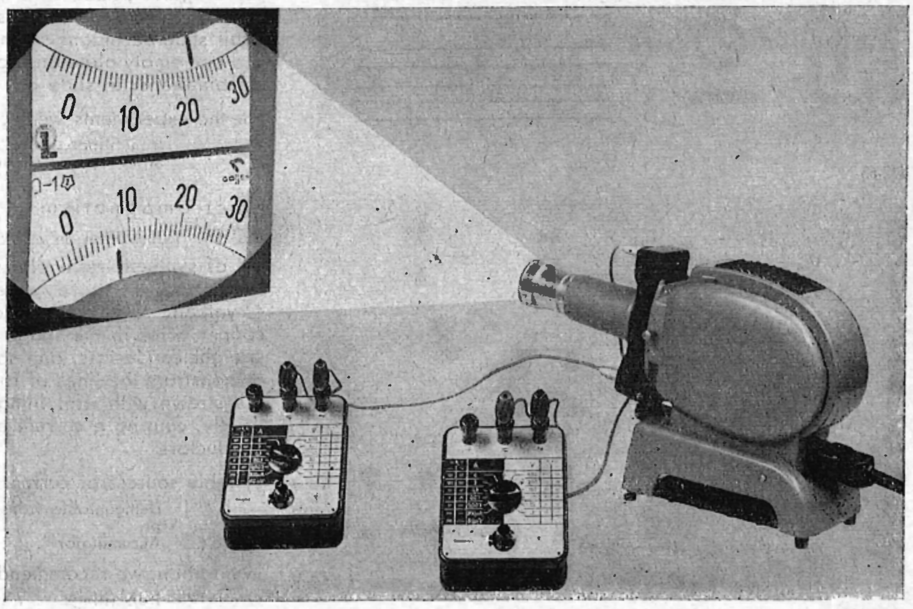


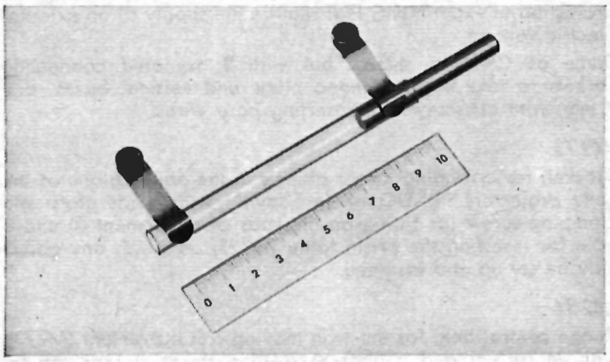
Fig. 56

PH 2044

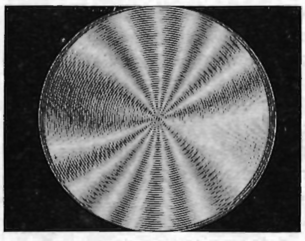
Waves

442 70

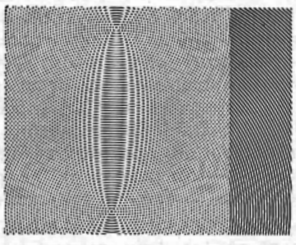
Kundt's tube for projection, for measuring the wavelength of short, standing sound waves in projection, also suitable for filling with various gases. Glass tube, approx. 11 cm long, dia. 10 mm; the plug has an axial hole for the admission of gases. With transparent scale with millimetre graduation and two spring clips for arrangement on the base plate (442 60); complete with cork dust.



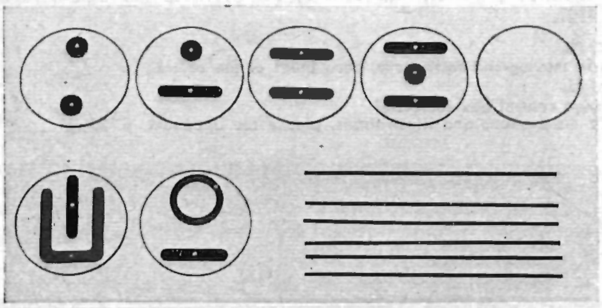
442 70



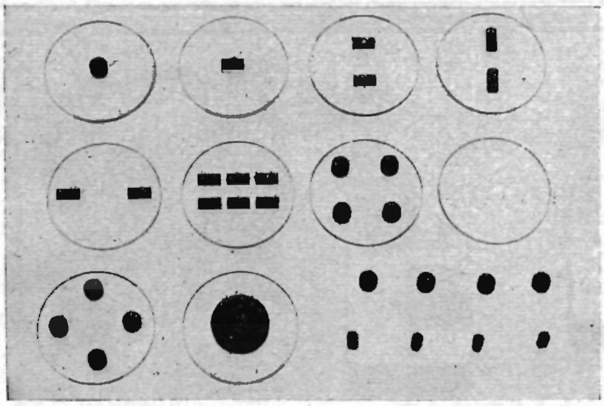
442 71 (projected image)



415 04 (projected image)



442 63



442 62

442 71

Interference model, according to Professor Pohl, similar to Cat. No. 415 04, but with 6.5×5 cm² and 11×5 cm² size plates; suitable for vertical projection using the Leitz projectors PRADO, "pradovit" or a projection arrangement as shown on p. 72 with the support for the object plate (442 90) as object holder.

415 04

Interference model, according to Professor Pohl, consisting of two transparent plastic plates with concentric systems of rings printed on them. When these are laid on top of one another, they can be used to demonstrate the origin of interference by slightly drawing their centres apart.

The plates are 9×9 cm² and 9×12 cm² in size; they are shown most impressively in vertical projection. For this, use the projection arrangement on p. 78, with the projection frame (441 51) as object holder.

Electrostatics

442 63

Set of glass plates with electrodes, for vertical projection on the base plate with connecting sockets (442 61).
6 glass plates, dia. approx. 50 mm, with cemented-on metal electrodes in characteristic arrangements. These plates are supplied with h. t. and the lines of force of the electric field produced are rendered visible, either with strewn-on plastic fibres, or with semolina in castor oil.

Supplied with one set of connecting wires; in slide magazine (442 89) of transparent plastic. For experiments in oil, the flat glass cell (442 68) is additionally required.

As source of voltage we recommend:

High-tension power supply	522 37
or	
Van de Graaff generator	541 70
or	
Demountable transformer 562 11/13/14 or 15 and	562 16

For the experiments we recommend ordering in addition:

Plastic fibres	545 13
Sifter-top jar for plastic fibres	514 79

Magnetism

442 62

Set of glass plates with magnets, for vertical projection on base plate (442 60). 9 glass plates, dia. approx. 50 mm, with small sintered magnets cemented on in various arrangements, and one empty plate and some loose magnets for making other combinations; in slide box (442 89) of transparent plastic.

For the experiments we recommend:

Iron filings, 250 g	514 73
Sifter-top jar for iron filings	514 72

Electromagnetism

442 64 (Illustration on p. 105)

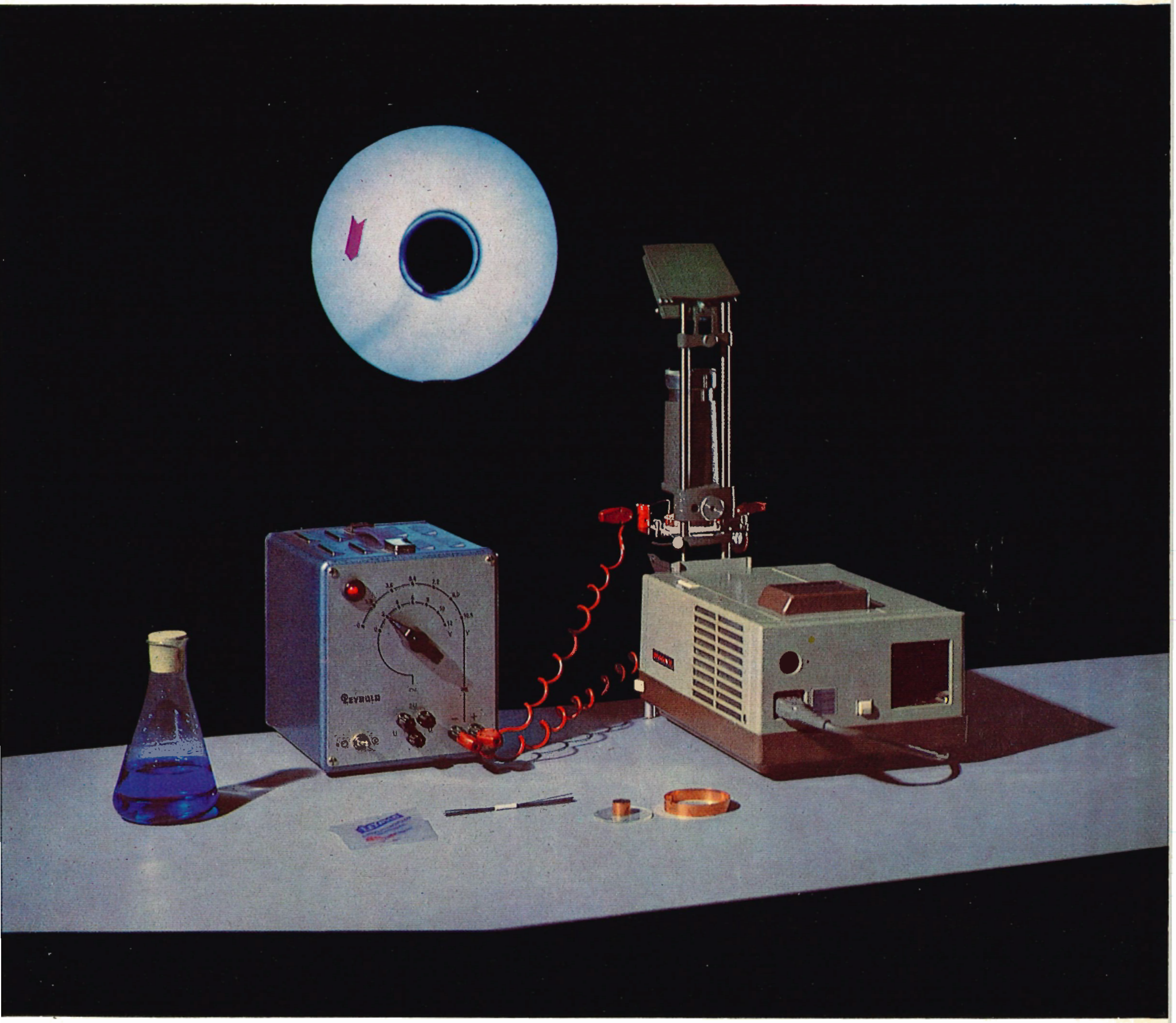
Set of synthetic-resin plates with conductors, for vertical projection on the base plate with connecting sockets (442 61). 4 synthetic resin plates, dia. approx. 50 mm, with moulded-in copper wires in the shape of a single straight conductor, two straight conductors, one solenoid and one toroid. In order to demonstrate the lines of force of the magnetic field, the plates are strewn with iron filings and a voltage of 1 V is applied briefly, causing a current of approx. 15 A to pass through the conductors.

Suitable sources of current are:

Demountable transformer	562 11/12/15/18
or	
Accumulator	522 73

In addition, we recommend:

Iron filings	514 73
Sifter-top jar for iron filings	514 72



The vertically directed field
of a circular magnet
and a radially directed electric field
produce a circular motion
of the electrolyte due to ionic friction.

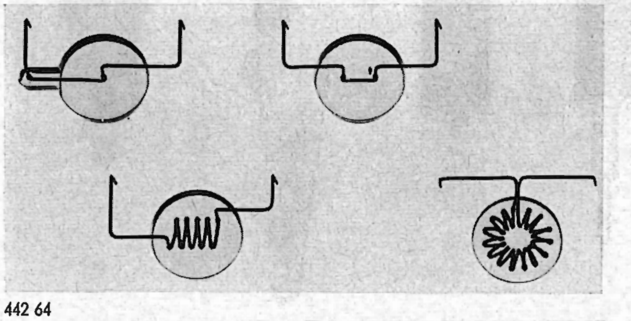
PLATE VIII

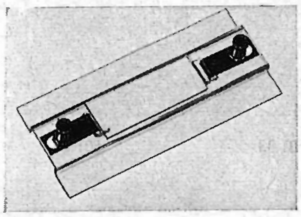
Electric conduction in liquids

442 65

Flat cell for demonstrating ion migration, for vertical projection, to be arranged on base plate (442 60). For demonstrating the migration of coloured ions and for measuring ionic mobility. Particularly suitable ions are permanganate ions in potassium nitrate solution. The electrodes of the cell are spaced about 80 mm apart. The electrolytic space between them is flat and has a recess for receiving potassium permanganate and other coloured salts.

The cell is made of transparent plastic with protruding base, lid, pure nickel electrodes, and connecting sockets.


442 64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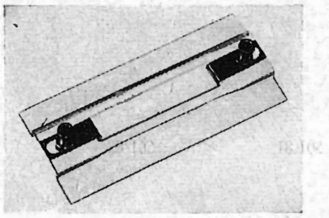
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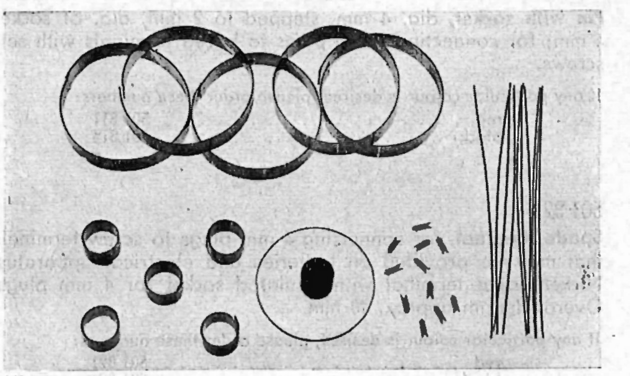
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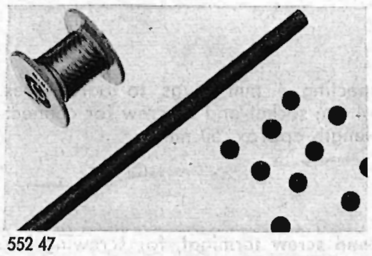
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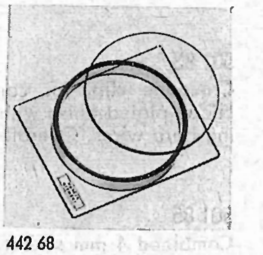
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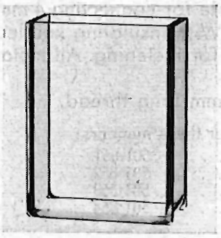
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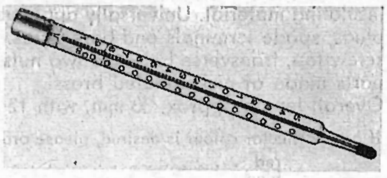

382 77

442 66

Flat cell for electrochemical experiments, for vertical projection, to be arranged on base plate (442 60), e.g. for studying the potential distribution in the case of homogeneous and inhomogeneous concentration of the electrolyte, conductivity determinations and similar experiments.

The cell is made of transparent plastic with protruding base, lid, and pure nickel electrodes and connecting sockets; the electrodes are spaced approx. 80 mm apart.

442 75

Equipment for demonstrating ionic friction, for vertical projection, to be arranged in glass dish (442 68) on the base plate with connecting sockets (442 61).

The equipment can be used to show that an ion current in a magnetic field will be deflected at right angles to its direction of flow and that the surrounding liquid will participate in its motion on account of ionic friction. The ion current is produced by two circular, concentric electrodes arranged about a vertical permanent magnet. Light plastic floating arrows indicate the resulting circulation of the liquid.

The equipment comprises a glass plate with cemented-on permanent magnet, 5 internal and 5 external annular copper electrodes, a set of 10 connecting electrodes and 10 plastic floating arrows.

552 47

Graphite rod and nickel wire. Graphite and pure nickel are particularly suitable for measuring the potential distribution in conductive and non-conductive liquids. Such measurements can easily be performed in vertical projection, using the round glass dish (442 68) and the base plate with connecting sockets (442 61). As high-resistance measuring instrument, we recommend the measuring amplifier (532 01).

The item includes:

1 Graphite rod, approx. 20 cm long, dia. approx. 10 mm
10 Graphite platelets
1 Coil of pure nickel wire, approx. 2 m of 1 mm dia. wire.

473 32

Nitrobenzene, chemically pure, for potential measurements and experiments with the Kerr cell (473 31).

442 68

Flat glass dish, round, for vertical projection of experiments in liquids, such as ionic friction, electrical lines of force in oil, mapping equipotential lines, and others. Round dish made of plate glass, dia. 50 mm, with protruding, rectangular base plate and lid.

304 60 (not shown)

Set of 3 watch glasses of different diameters, for experiments, e.g., with mercury drops.

442 69

Glass cell, for horizontal projection of experiments in liquids, such as surface tension, electrolysis, and others; made of plate glass, internal dimensions 80×60×25 mm^3.

382 77

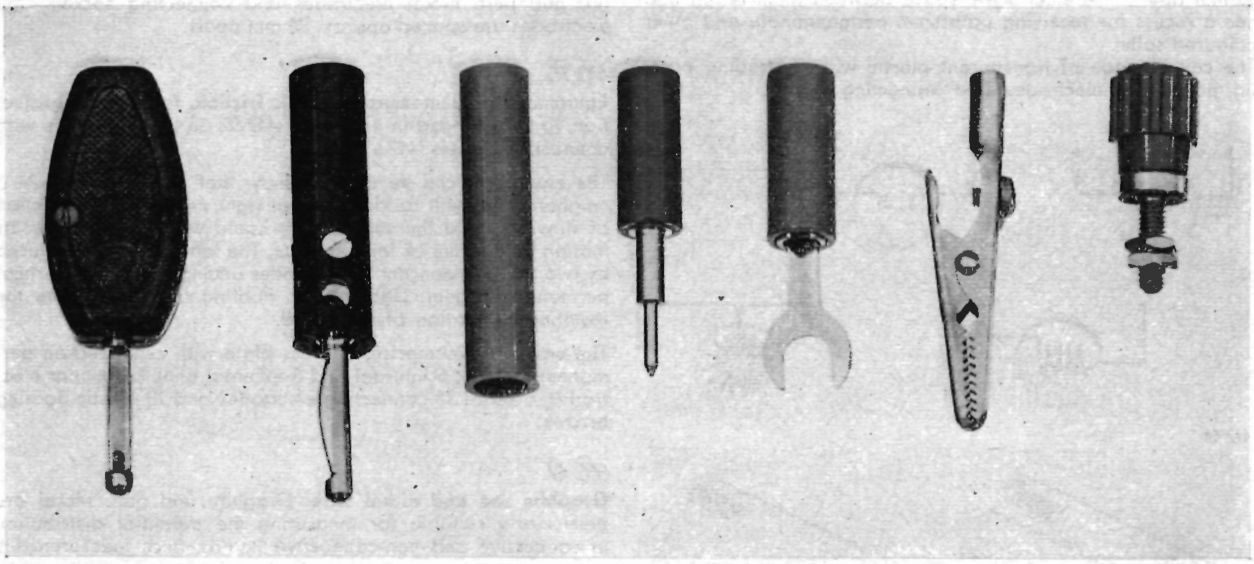
Projection thermometer, approx. 32 cm long, measuring range -50° C to +100° C, with 1° divisions. For projection, we recommend the arrangement shown on p. 78, but without projection frame (441 51).

442 89 (not shown)

Magazine box, for slides in frames, 50×50 mm^2, and other optical objects of equivalent size, such as coloured filters and the like. Several boxes can be stored one on top of the other. The slides are easily moved over into a projection magazine.

ELECTRICITY

Ancillary equipment for making electric connections



501 51 501 56 501 64 501 81 501 82 501 83 501 85

501 51

Leybold plug, safe-to-touch plug, dia. 4 mm, for safe and reliable experimenting with electric current. The plug has a flat, compact and easily handled shape. It can also be used for making multiple connections, because it has a 4 mm socket on top; thus any number of plugs can be inserted into one another and the corresponding number of branches can be led off. The connecting points of the leads introduced into these plugs are not subject to tensile stress. Approx. 60 mm long in all.

In case any particular colour is desired, please order these numbers:

red	501 511
blue	501 512
green	501 513
black	501 514
yellow	501 515

501 56

Plug, 4 mm long plug with top and side connections, for connecting other plugs, e.g. when making branch points. Also, a wire may be passed through the plug and retained with a screw. Approx. 60 mm long in all.

In case any particular colour is desired, please order these numbers:

red	501 561
blue	501 562
green	501 563
black	501 564
yellow	501 565

501 64

Two-way plug adaptor, for insulated connection of two 4 mm plugs (e.g. 501 51 or 501 56). The adaptor is insulated along its whole length of approx. 45 mm.

In case any particular colour is desired, please order these numbers:

red	501 641
black	501 644

501 81

Pin with socket, dia. 4 mm, stepped to 2 mm, dia. of socket 4 mm; for connecting 4 mm plugs to bored terminals with set-screws.

If any particular colour is desired, please order these numbers:

red	501 811
black	501 814

501 82

Spade terminal, for connecting 4 mm plugs to screw terminals that may be provided on batteries and electrical apparatus. Nickel-plated terminal with insulated socket for 4 mm plugs. Overall length approx. 40 mm.

If any particular colour is desired, please order these numbers:

red	501 821
black	501 824

501 83

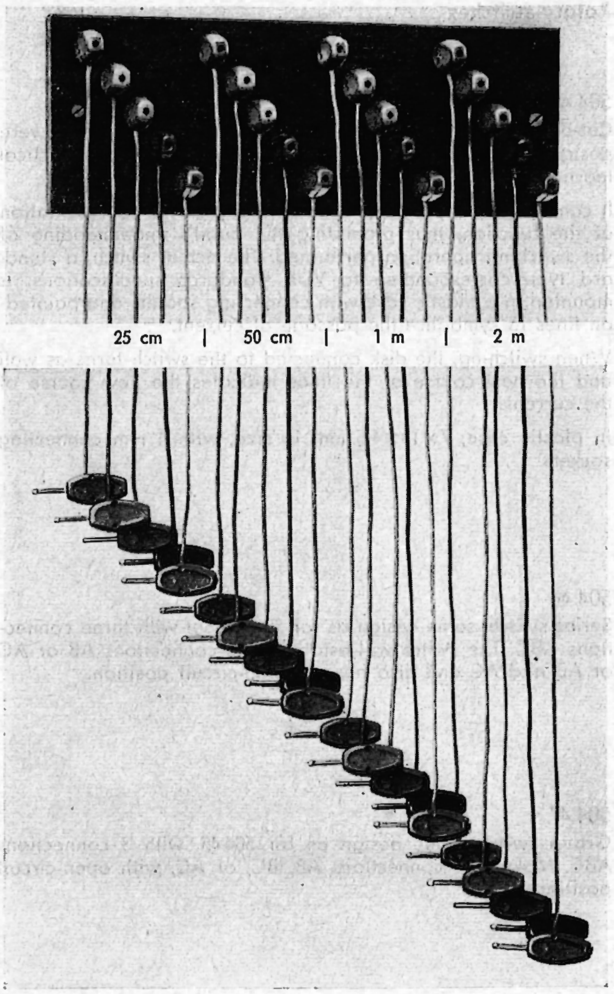
Crocodile clip, for connecting 4 mm plugs to bare wires. Nickel-plated finish with 4 mm socket and a screw for connecting bare wires. Overall length approx. 50 mm.

501 85

Combined 4 mm socket and screw terminal, for screwing into insulating material. Universally applicable for connecting 4 mm plugs, spade terminals and bare wires. With insulating knurled screw top, transverse hole and two nuts for fastening. All metal parts made of nickel-plated brass.
Overall length approx. 30 mm, with 12 mm long thread.

If any particular colour is desired, please order these numbers:

red	501 851
blue	501 852
green	501 853
black	501 854



501 98 (Cable board)
501 20–501 39

501 20–39
Connecting leads, with coloured plastic insulation and 1.5 mm² cross-sectional area of copper. Provided with two Leybold plugs each in the colour of the insulation, these leads are ideal to use, both for simple and more involved circuits with multiple connections.

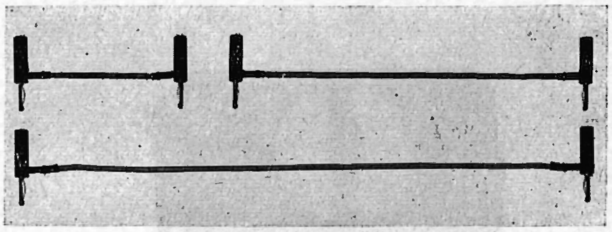
The connecting points of the wires are free from tensile stress and the leads and plugs are absolutely safe to touch.

The leads can be supplied in four different lengths and five colours. It has been found practical always to obtain pairs of leads of one kind.

Length	25 cm	50 cm	1 m	2 m
red	501 20	501 25	501 30	501 35
blue	501 21	501 26	501 31	501 36
green	501 22	501 27	501 32	501 37
black	501 23	501 28	501 33	501 38
yellow	501 24	501 29	501 34	501 39

501 98
Cable board for connecting leads; for tidy and convenient storage of connecting leads, to be mounted on a wall.

Wooden board, approx. 12.5×33 cm² in size, with 20 holes arranged in 4 slanting rows. Each hole is capable of taking up to 4 plugs inserted into one another.



501 89–91

501 89–91
Elastic connecting leads. Unlike the types usually found, these leads can be extended up to twice their unstretched length, which makes for taut connections. For this reason arrangements in which these leads are used will appear particularly clear. When working with h. t. these leads are also very suitable because they will not touch anywhere so that sparking does not occur.

The leads contain a copper conductor that is woven tube-like about an elastic core. The outer cover consists of a resistant white perlon insulation. Both ends are well insulated and connected to 4 mm plugs. The leads can be loaded up to approx. 6 A.

Cat. No.	Normal length	Max. length when stretched
501 89	10 cm	20 cm
501 90	25 cm	50 cm
501 91	40 cm	80 cm

501 97 (not shown)
Connecting cable, approx. 2 m long, 3-core, each strand having a copper cross-sectional area of 1.5 mm², with Schuko plug and apparatus socket (earthed and insulated) and built-in on-off switch.

540 52 (see illustration on p. 127)
Demonstration insulator, made of a new cast synthetic resin that combines a high insulation resistance with great mechanical strength. Connections are made by three 4 mm bores on the high tension side, one of these being axial and the other two radial ones. A clamping screw facilitates the connection of wires.

On the other side a bore for the connection of an earth conductor is provided.

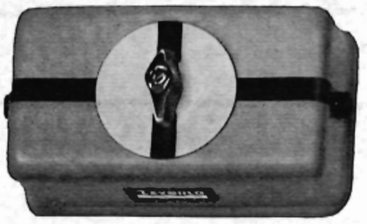
Length of the insulator: approx. 5.5 cm, overall length approx. 14 cm; insulation resistance $>10^{14}\ \Omega$, breakdown voltage: 15 kV.

502 00 (not shown)
Distributor board, with 4 Schuko mains sockets, for use on the workbench. This has been found particularly useful for instruction outside the physics laboratory.

Complete with three-core connecting cable with Schuko safety plug, 2 m long.

505 03 (not shown)
Mains tester for A.C., minimum voltage approx. 100 V; glowlamp and series resistor are contained in the transparent, insulating handle of the screw-driver which has the approximate shape of a ball-point pen; overall length approx. 12 cm, with protective cap.

Rotary switches



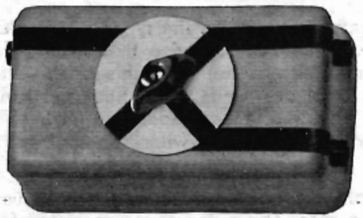
504 45

504 45
Cut-out switch. This switch and the following types were designed in accordance with the requirements of practical teaching.

It combines safety of operation with impressive representation of the function, thus promoting the pupil's understanding of the switching operation performed. The actual switch, a standard type corresponding to VDE standards specifications, is mounted in a plastic case with connecting sockets and painted-on lines to symbolise the passage of current.

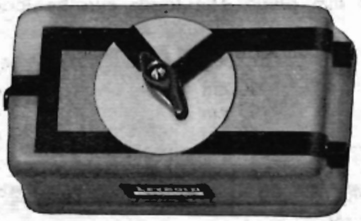
When switching, the disk connected to the switch turns as well and the new course of the lines indicates the new course of the current.

In plastic case, 7×13×4.5 cm³ in size, with 4 mm connecting sockets.



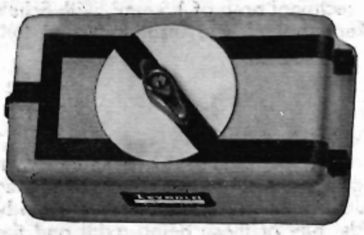
504 46

504 46
Series switch, same design as for 504 45, but with three connections ABC. The switch will establish the connections AB or AC or AB **and** AC and also has an open-circuit position.



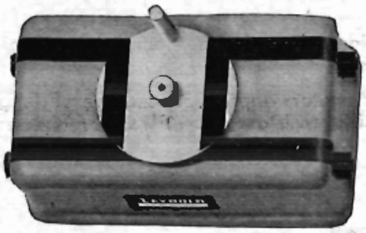
504 47

504 47
Group switch, same design as for 504 45, with 3 connections ABC. Makes the connections AB, BC, or AC, with open-circuit position.



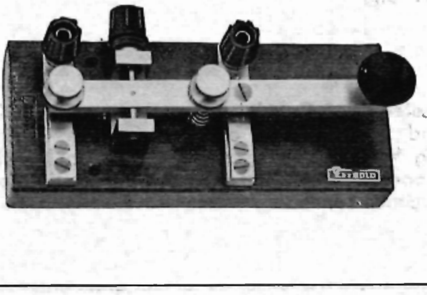
504 48

504 48
Two-way switch, same design as for 504 45, with 3 connections ABC. The switch enables the connections AB or AC to be made.



504 49

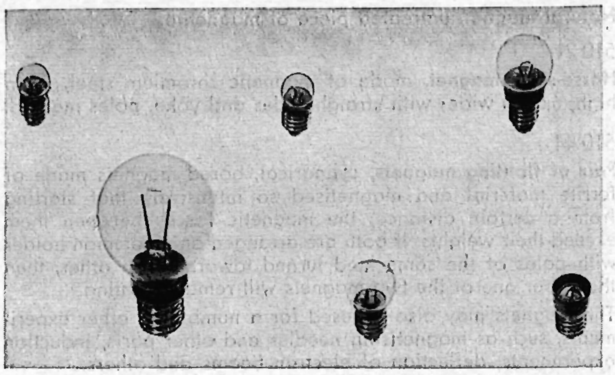
504 49
Commutator switch, same design as for 504 46, but with connecting sockets ABCD. The switch will make the connections AB and CD, or the connections AC and BD. This switch can be used as a polarity inverter to invert the sense of a current. If it is rotated continuously, one can also produce an alternating current with square current pulses. In order to facilitate turning, this switch has an operating lever arranged off-centre as a crank instead of the usual knob.



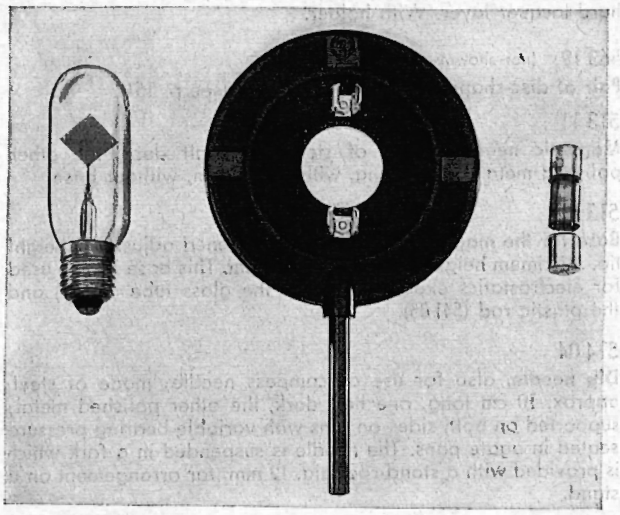
504 52

504 52
Morse key, for short-duration making and breaking of circuits, e.g. when measuring short periods of time with the electric stop clock; key, pivot support and contact strips are made of brass, with German-silver contacts; adjustable contact spacing; with return spring and three terminals for connecting two circuits; on base board.

505 11 505 12 505 13

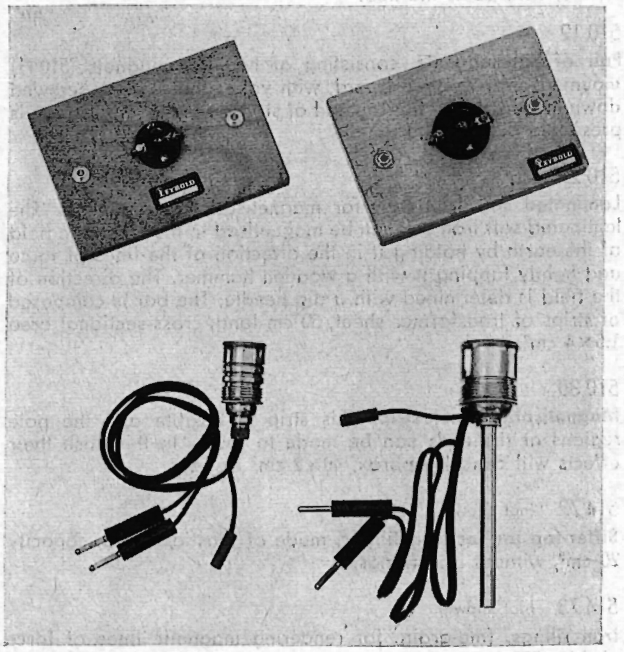


450 51 505 18 505 14



505 38/37 505 40 505 39

505 66 505 67



505 68 451 18

Incandescent lamps and glow lamps

Cat. No.	Voltage V	Power W	Screw cap	Particularly suited for
505 11	2.5	0.25	E 10	Introductory experiments
505 12	3.5	0.7	E 10	Introductory experiments
505 13	6	5	E 10	Tesla transformers
505 14	6	3	E 10	Models of electrical machines
450 51	6	30	E 14	Projection, optical experiments
505 18	24	3	E 10	Models of electrical machines

505 38

Glow lamp, 220 V, with triangular electrodes and built-in resistor for direct connection to 220 V, with E 27 screw cap.

505 37

Glow lamp, 110 V, otherwise same as for 505 38.

505 39

Glow lamp for demonstrating saw-tooth oscillations. In the case of this glow lamp, the difference between the striking and quenching voltages is very high. For this reason it is particularly suitable for producing saw-tooth oscillations. Approx. 60 mm long, dia. 20 mm, tubular, without holder. We recommend using holder (505 40).

For generating and detecting saw-tooth oscillations, the following parts are additionally required:

Power supply	522 33/35
Resistor, 100 kΩ	536 25
Condenser, e.g. 0.1 μF	538 05
Speaker	580 05
or	
School cathode ray oscilloscope	575 15

505 40

Holder for the glow lamp for demonstrating saw-tooth oscillations, for glow-lamp (505 39), and other tubular lamps, with 4 mm connecting sockets, on rod, dia. 10 mm.

505 66

E 10 screw socket, for incandescent lamps with E 10 screw cap (505 11 to 505 18); on board, 15×10 cm² in size, with rubber pads and 4 mm connecting sockets.

505 67

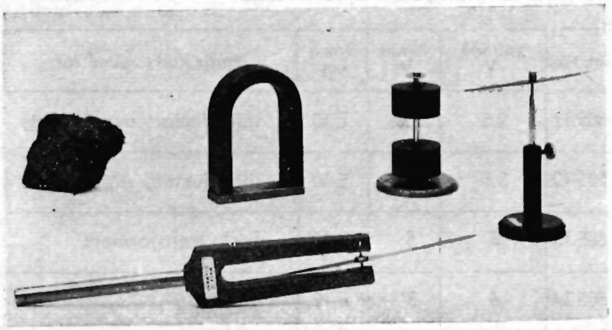
E 14 screw socket, for incandescent lamps and two-electrode tubes with E 14 screw cap, otherwise same as for 505 66.

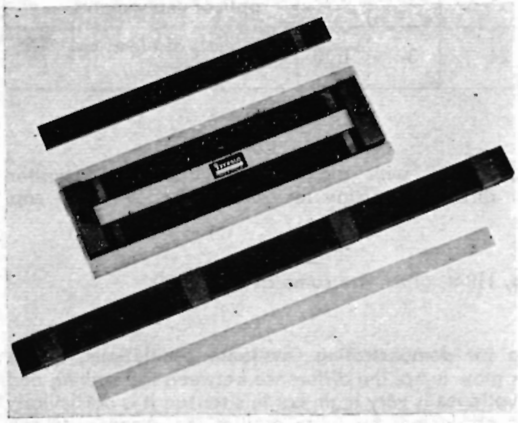
505 68

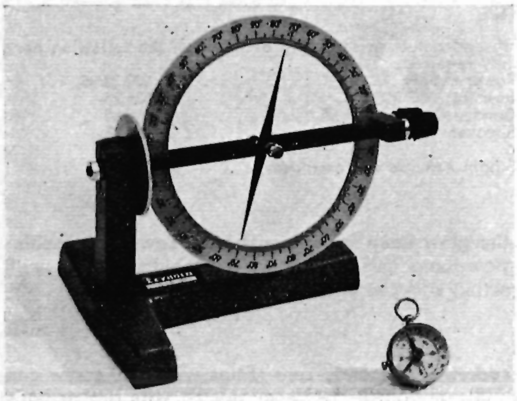
E 14 screw socket, with connecting cable, 75 cm long, with plugs. Another connection provided on the socket enables it to be used for experiments with the field emission electron microscope (554 60).

451 18

E 27 screw socket, for incandescent lamps and for the mercury vapour lamp (451 15); on rod, dia 10 mm, with connecting cable, approx. 70 cm long, and plugs. The third connection provided on the socket itself is needed when using the socket for the experiments with the field emission electron microscope (554 60).







513 70
Pocket compass, with agate pan bearing the magnetic needle, and arresting device, in brass case, dia. 30 mm.

514 02
Dip circle, with provision for measuring magnetic declination, for finding the magnetic meridian, for determining the inclination and for measuring the deflection of a magnetic needle by an electric current; can also be used as an accessory for measuring magnetic poles with the torsion balance (516 01) (cf. pp. 111–113).
The steel needle is supported on both sides in agate bearing pans on points with adjustable bearing pressure. The graduated circle, dia. approx. 140 mm, is divided in degrees and can be turned about its horizontal axis. Horizontal and vertical position can be checked on a scale divided in units of 1°. Parallel to the horizontal axis of the graduated circle, a conducting loop is provided which is made of solid brass, and held by an insulator with connecting sockets (4 mm). Complete with support.

510 01
Natural magnet, untreated piece of magnetite.

510 21
Horse-shoe magnet, made of magnetic chromium steel, 9 cm high, 6.5 cm wide; with straight sides and yoke, poles marked.

510 44
Pair of floating magnets, cylindrical, bored magnets made of ferrite material and magnetised so intensively that starting from a certain distance, the magnetic forces between them exceed their weights. If both are arranged on a common holder with poles of the same kind turned towards each other, then the upper one of the two magnets will remain floating.
The magnets may also be used for a number of other experiments, such as magnetising needles and other parts, induction experiments, deflection of electron beams and others.
Each magnet is approx. 20 mm high, and has a diameter of 35 mm. In order to protect it from damage, it is covered with a hard lacquer layer. With holder.

563 19 (not shown)
Pair of disc-shaped permanent magnets (see p. 151).

513 11
Magnetic needle, made of steel, one half dark, the other polished metal; 10 cm long, with agate pan, without base.

513 51
Base for the magnetic needle, with hardened adjustable-height tip. Maximum height of tip approx. 10 cm. This base is also used for electrostatics experiments with the glass tube (541 02) and the plastic rod (541 05).

514 04
Dip needle, also for use as compass needle; made of steel, approx. 10 cm long, one half dark, the other polished metal; supported on both sides on pins with variable bearing pressure seated in agate pans. The needle is suspended in a fork which is provided with a stand rod, dia. 12 mm, for arrangement on a stand.

510 11
Bar magnet, made of magnetic chromium steel, 30×2.5×0.7 cm^3 in size, with poles marked.

510 12
Pair of bar magnets, consisting of two bar magnets (510 11) mounted on a wooden board, with yokes that can be screwed down in storage. By this method of storage the magnetisation is preserved over a long time.

510 29
Laminated soft iron bar, for magnetisation experiments. The laminated soft iron bar can be magnetised in the magnetic field of the earth by holding it in the direction of the lines of force and lightly tapping it with a wooden hammer. The direction of the field is determined with a dip needle. The bar is composed of strips of transformer sheet, 50 cm long, cross-sectional area 1.5×4 cm^2.

510 35
Magnetisable steel strip. This strip is flexible and the pole regions at the ends can be made to touch. In this case their effects will cancel. Approx. 40×2 cm^2 in size.

514 72 (not shown)
Sifter-top jar for iron filings, made of plastic, round, capacity 20 cm^3, without iron filings.

514 73 (not shown)
Iron filings, fine-grain, for rendering magnetic lines of force visible; 250 g.

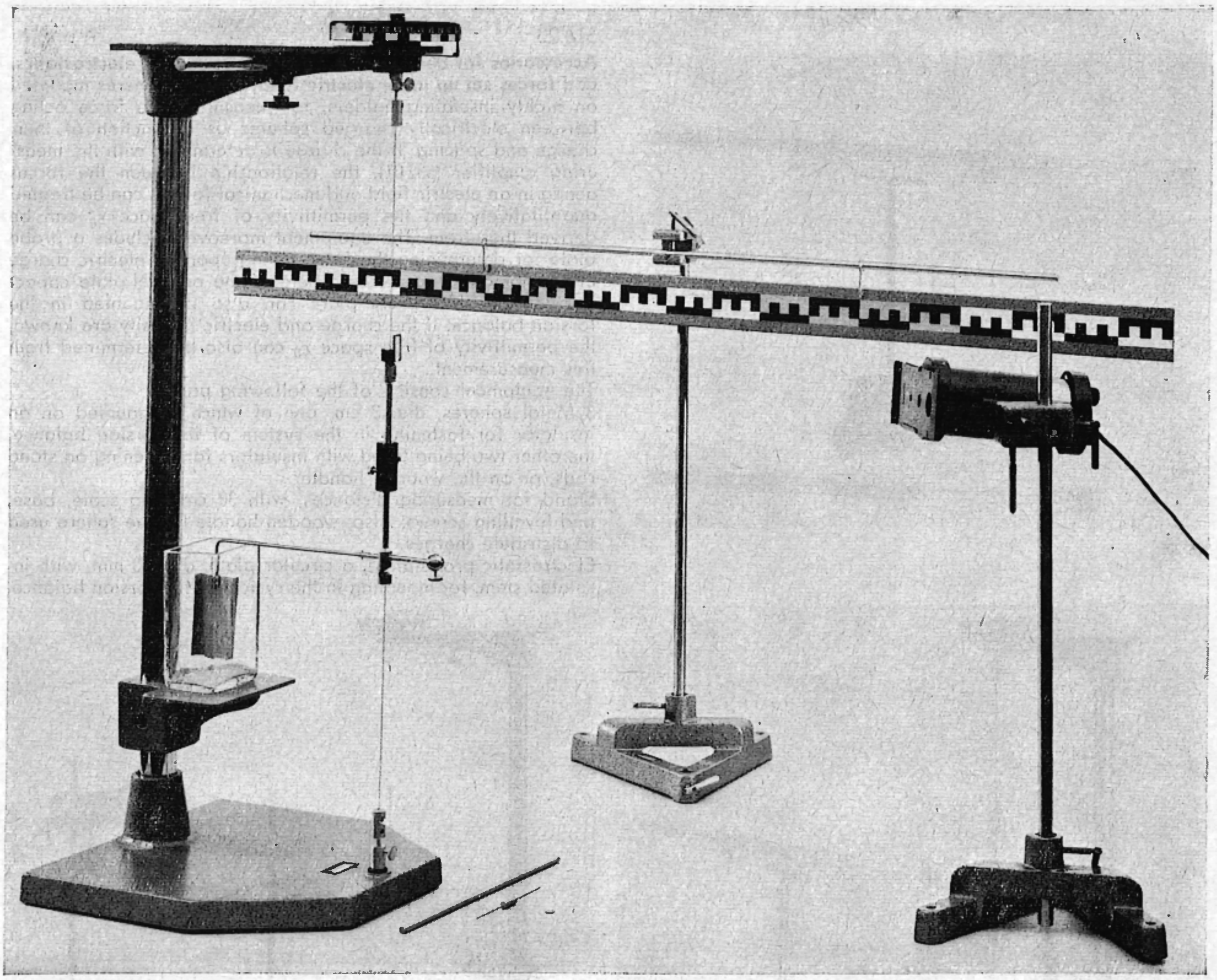


Fig. 70 Torsion balance, Schürholz design, (516 01), with illuminating device (516 02) and scale on stand (516 04). PH 2039

Torsion balance

516 01

Torsion balance, Schürholz design; for measuring small torques. This apparatus permits the treatment of laws of physics on which experiments cannot be performed by other means in school teaching; e.g. Coulomb's laws of electrostatics and magnetostatics, on the forces set up in homogeneous electric fields, on the magnetic field of straight and circular conductors and the force acting on a current-carrying loop in the magnetic field. In addition to their suitability for demonstrations, these measurements also provide excellent subject-matter for practical work.

The restoring force of the sensitive system of the balance is approx. 6,000 dyne · cm (= 6×10^{-4} Nm). Therefore a torque of 30 dyne · cm will produce a 1 cm deflection of the spot of light on a scale 1 m away. If a moment arm of 5 cm is used, this moment of a force or torque corresponds to a force of 6 dynes [= approx. 6 millipond (mg wt)]. This sensitivity is sufficient for the above-mentioned applications; it can be determined by static or dynamic methods in a simple manner. Simple instructions for this, and also for the various experiments, are supplied with the apparatus. The apparatus consists of:

1 Frame on heavy base plate, approx. 70 cm high, made of aluminium and brass without the use of iron, with a torsion head with graduated circle, divided in 5°, suspension device for the sensitive system and support for the damping device.

1 Sensitive system with two thin steel wires between which the holder for inserting the experimental objects is suspended. This bar-shaped holder also takes the hollow mirror and the damping vane; with concave mirror, 10×20 mm², f = approx. 35 cm, for producing the spot of light on a distant scale.

The accessories supplied with the balance are:
1 Bar for dynamic calibration,
1 Bar for static calibration,
1 Damping vane and 1 vessel in which to insert same,
1 Pair of spare torsion wires for the system.
The balance is supplied without illuminating device and without the accessories listed below.

For descriptions of experiments, see "LEYBOLD Physics Leaflets", DC 531.781; a, DC 537.211; a, b, and d, DC 538.311; a, DC 538.312; a, DC 538.51; a

516 02

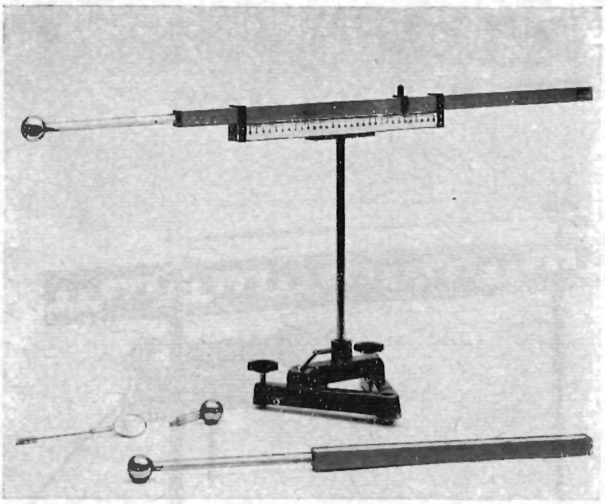
Illuminating device, for lamp-and-scale arrangements and other assemblies, such as experiments with: torsion balance (516 01), double wire loop oscillograph (560 43), centrifugal force apparatus (347 22), cloud chamber (559 57), and smoke chamber (Brownian motion, 372 51).

The equipment consists of the following parts, which can also be ordered separately:

Lamp-house	450 60
Lamp, 6 V, 30 W	450 51
Single-lens condenser with aperture slide	460 17
Stand base	300 02
Stand rod	300 42
Leybold boss	301 01

516 04

Scale, made of metal, 1 m long, with coloured centimetre graduation, on stand, laterally and vertically adjustable. Complete with stand, stand rod, and Leybold boss.



516 20

516 20

Accessories for demonstrating Coulomb's law of electrostatics, and forces set up in an electric field; set of 3 spheres mounted on highly insulating holders, for measuring the force acting between electrically charged spheres as a function of their charge and spacing. If the charge is determined with the measuring amplifier (532 01), the relationship between the forces acting in an electric field and mechanical forces, can be treated quantitatively and the permittivity of free space ε_0 can be derived therefrom. The equipment moreover includes a probe plate for determining the force acting upon an electric charge in the homogeneous electric field of the parallel-plate capacitor (544 22). This probe-plate can also be mounted in the torsion balance. If the charge and electric intensity are known, the permittivity of free space ε_0 can also be determined from this measurement.

The equipment consists of the following parts:

3 Metal spheres, dia. 3 cm, one of which is mounted on an insulator for fastening in the system of the torsion balance, the other two being fitted with insulators for fastening on stand rods, or on the wooden handle,

Stand for measuring distances, with 30 cm long scale, base, and levelling screws. Also, wooden handle for the sphere used to distribute charges,

Electrostatic probe-plate, a circular plate, dia. 40 mm, with insulated stem, for mounting in the system of the torsion balance.

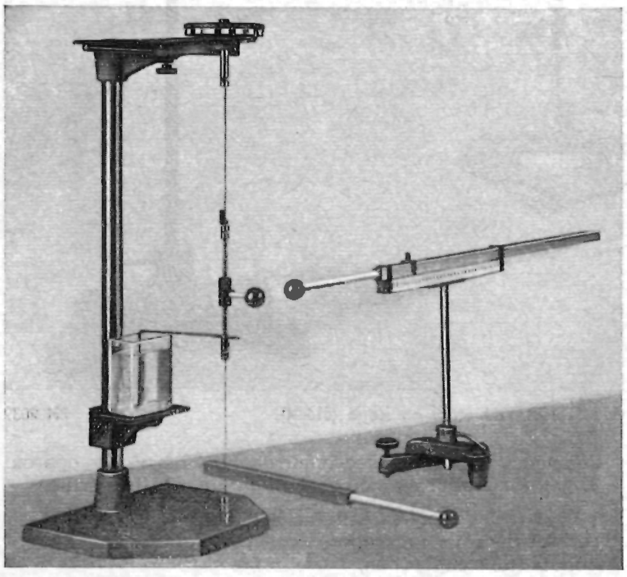


Fig. 71 PH 2040
Demonstration of Coulomb's law of electrostatics with the torsion balance (516 01) and the accessories 516 20. For this experiment, the illuminating device 516 02 is required.

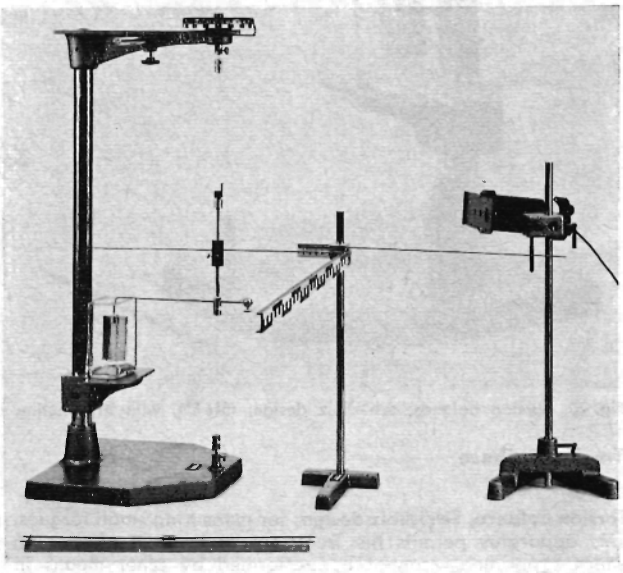
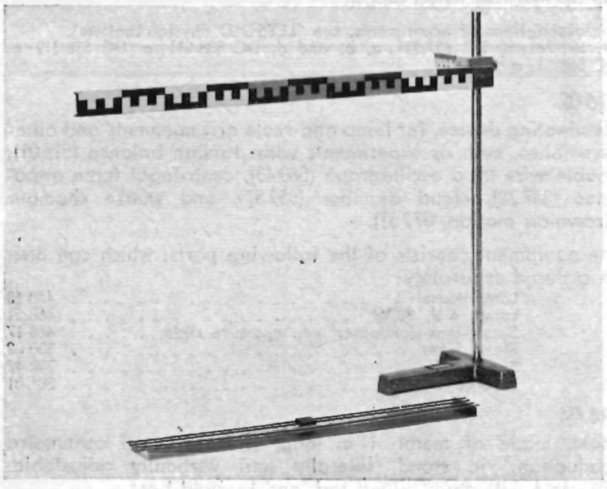


Fig. 72 PH 2041
Verification of Coulomb's law of magnetism with the torsion balance (516 01), the accessories 516 21, and the illuminating device 516 02.



516 21

516 21

Accessories for experiments on magnetostatics, for measuring the magnetic induction near the poles of long magnetic needles, and the pole strengths and magnetic moments of such magnetic needles, and for verifying Coulomb's law of magnetostatics. For these measurements, one magnetic needle is inserted into the system of the torsion balance, and the other is mounted on a stationary stand. The torsion balance will then indicate the forces set up between the two needles under the various conditions set up by the experimenter.

The equipment comprises the following parts:

- 4 Steel needles, approx. 40 cm long, 2 of these with cylindrical central section for mounting in the torsion balance,
- 1 Iron frame for storing the needles,
- 1 Stand for setting up 1, 2, or 3 needles, made of non-magnetic material, with horizontal, 50 cm long scale and with a second scale at right angles to it, for exact determination of the location of the pole regions.

516 22 (Cf. also the illustration on p. 141)

Set of solenoids, for determining the relation between the magnetic induction set up in and around the solenoids, the number of turns per cm and the current passed through them, and to show that the magnetic induction does not depend upon the cross-sectional area of the solenoids. For these measurements a small magnetic needle is inserted into the system of the torsion balance and the magnetic induction prevailing at any point in the field is determined from the torque on the needle.

The solenoids can, moreover, also be used for quantitative experiments on electromagnetic induction, or to make electric oscillatory circuits with easily calculated inductance.

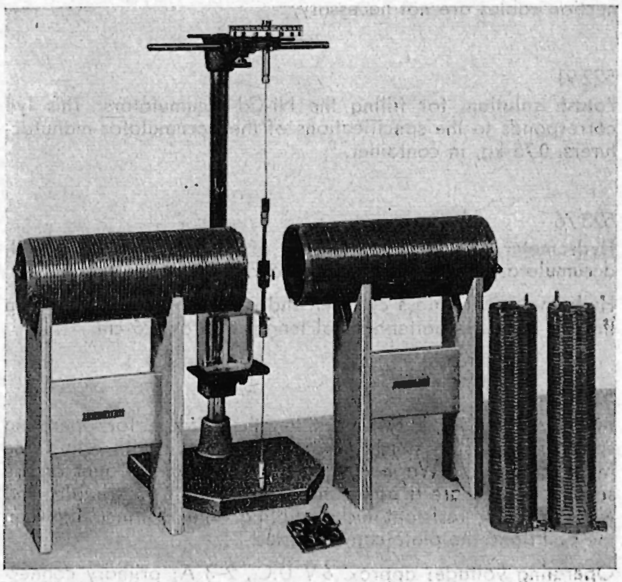
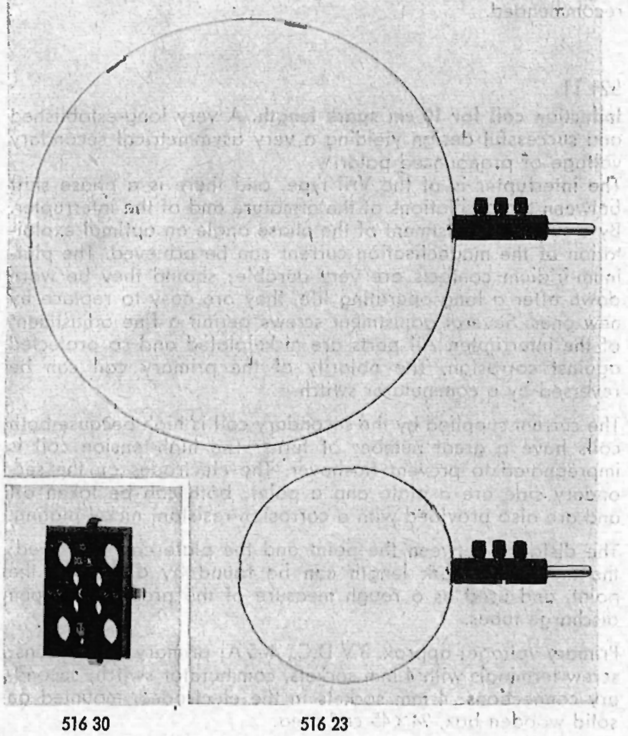


Fig. 73 PH 2042
Measurement of the magnetic induction due to current-carrying solenoids using the torsion balance (516 01), and the set of solenoids (516 22): For this experiment, the illuminating device 516 02 is needed.



The set consists of:

- 2 Solenoids, approx. 31 cm long, dia. 120 mm, without iron, which, when plugged to one another, will form a solenoid with two separate windings of 120 turns each, and 60 cm length; that can be loaded up to approx. 5 A, with connecting sockets.
- 2 Solenoids, as described above, except for dia. 70 mm and one winding of 120 turns.
- 2 Wooden supports to carry the solenoids during experiments with the torsion balance.
- 1 Magnetic rod, approx. 30 mm long, dia. 6 mm.

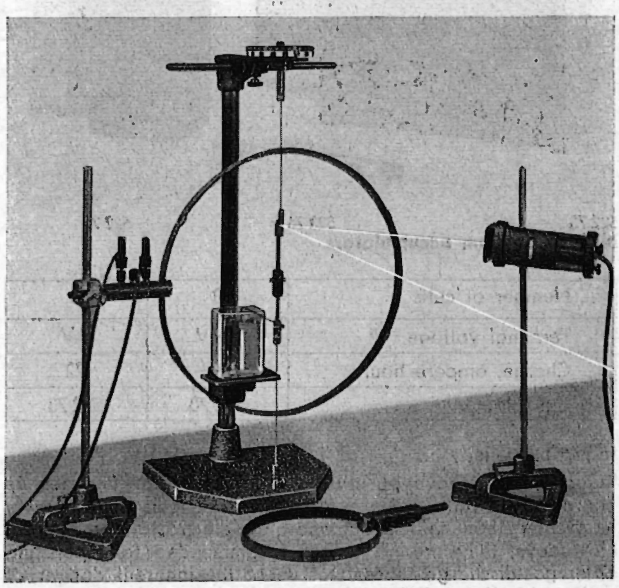


Fig. 74 PH 2043
Verification of Biot and Savart's law, using the torsion balance (516 01), the accessories 516 23, and the illuminating device 516 02.

516 23

Accessories for demonstrating Biot and Savart's law, for determining the relation between the magnetic field at the centre of a circular current-carrying conductor, and its current, number of turns and diameter. For these experiments, a small magnetic rod is inserted into the torsion balance, the latter indicating the torque exerted upon this bar by the magnetic field.

The set comprises:

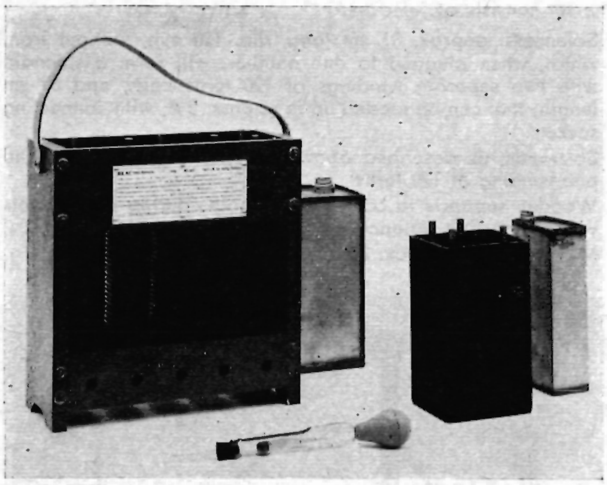
- 1 Circular coil, dia. 400 mm, 10 turns with centre tap, 3 connecting sockets provided on the rod by which it may be held and mounted on a stand,
- 1 Circular coil, dia. 200 mm, otherwise same as above,
- 1 Magnetic rod, approx. 30 mm long, dia. 6 mm.

516 30

Wattmeter- and probe-coil, for experiments with the torsion balance (516 01) and the set of solenoids (516 22).

With the use of this coil, the forces exerted by a magnetic field upon a rectangular current-carrying conductor can be measured and an electrodynamic wattmeter for the range from a few watts up to 1 kW can be assembled. Moreover, the arrangement may be used together with a ballistic galvanometer (e.g. 532 10) in order to determine the permeability of free space and the ballistic voltage sensitivity of the galvanometer.

The coil has 100 turns and is wound on a rectangular former, 50×70 mm² in size. It can take currents of up to approx. 300 mA. The former is provided with a rod for clamping in the system of the torsion balance, and spring contacts for current supply via the torsion wires of the balance.

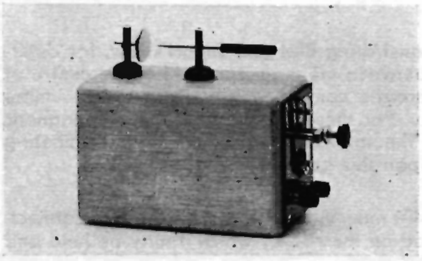


Nickel-Cadmium accumulators

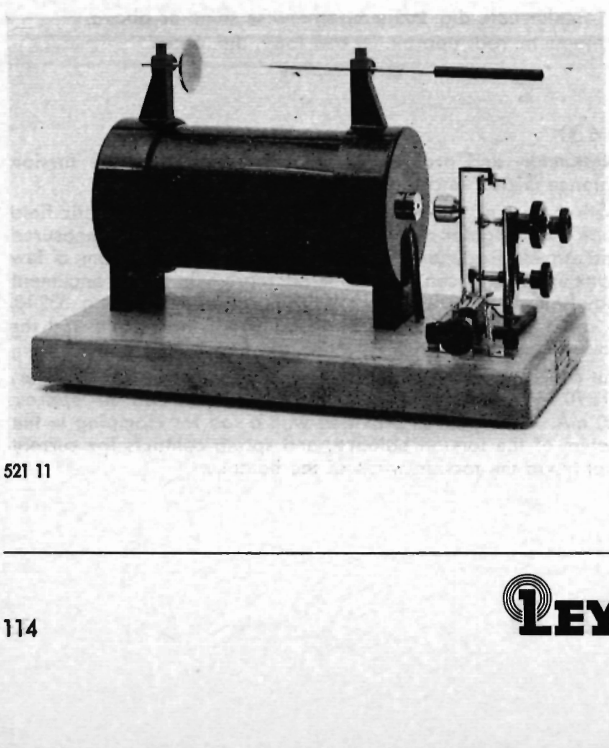
Number of cells	3	5
Terminal voltage	3.6 V	6 V
Charge, ampere hours	11	22
Cat. No.	522 70	522 73

Induction coils

Induction coils have been used in teaching for decades as sources of current for X-ray tubes, because their output power is greater than that of comparable electrostatic machines. Nowadays, they are no longer recommended for operating other gas-discharge tubes because of the inherent danger of undesirable X-rays being produced, but are still recommended for operating X-ray tubes provided the safety measures are observed as outlined on pages 137 and 179.



521 02



521 11

522 70 / 522 73

Nickel-Cadmium accumulators are highly recommended for teaching and laboratory purposes on account of their long life and because they require only little maintenance and can be heavily loaded for short periods. Each accumulator consists of several cells housed in a common casing. They are supplied almost completely discharged, and unfilled. The potash solution is supplied with them in a separate container, and the accumulators must be filled in accordance with the accompanying directions.

The cell terminals are lengthened to facilitate connections, and provided with 4 mm sockets. Therefore, as a rule, special connection cables are not necessary.

522 91

Potash solution, for filling the Ni-Cd-accumulators. This lye corresponds to the specifications of the accumulator manufacturers. 0.75 kg, in container.

523 76

Hydrometer, for testing the state of charging of the Ni-Cd-accumulator, by determining the concentration of the lye.

Hydrometer with glass cylinder and rubber ball for sucking up the lye from the battery. Total length approx. 26 cm.

521 02

Induction coil for 3 cm spark length, suitable for operating spectrum lamps. A sturdy piece of equipment with adjustable interrupter of the Wagner hammer type. The electrodes on the secondary side are a point and a plate, both detachable, and with corrosion-resistant nickel plating. The distance between the point and the plate can be varied.

Operating voltage: approx. 6 V D.C., 2–3 A; primary connections: screw terminals with 4 mm sockets, secondary connections 4 mm sockets in the electrodes; in closed, stained wooden box, 9×11×18 cm³ in size.

The operation of X-ray tubes with this induction coil is not recommended.

521 11

Induction coil for 10 cm spark length. A very long-established and successful design yielding a very asymmetrical secondary voltage of pronounced polarity.
The interrupter is of the Vril type, and there is a phase shift between the oscillations of the armature and of the interrupter. By a suitable adjustment of the phase angle an optimal exploitation of the magnetisation current can be achieved. The platinum-iridium contacts are very durable; should they be worn down after a long operating life, they are easy to replace by new ones. Several adjustment screws permit a fine adjustment of the interrupter. All parts are nickelplated and so protected against corrosion. The polarity of the primary coil can be reversed by a commutator switch.

The current supplied by the secondary coil is high because both coils have a great number of turns. The high-tension coil is impregnated to prevent flashover. The electrodes on the secondary side are a plate and a point; both can be taken off and are also provided with a corrosion-resistant nickel plating.

The distance between the point and the plate can be varied; the maximum spark length can be found by displacing the point, and used as a rough measure of the pressure in open discharge tubes.

Primary voltage: approx. 8 V D.C., 4–5 A; primary connections: screw terminals with 4 mm sockets, commutator switch; secondary connections: 4 mm sockets in the electrodes; mounted on solid wooden box, 24×45 cm² area.

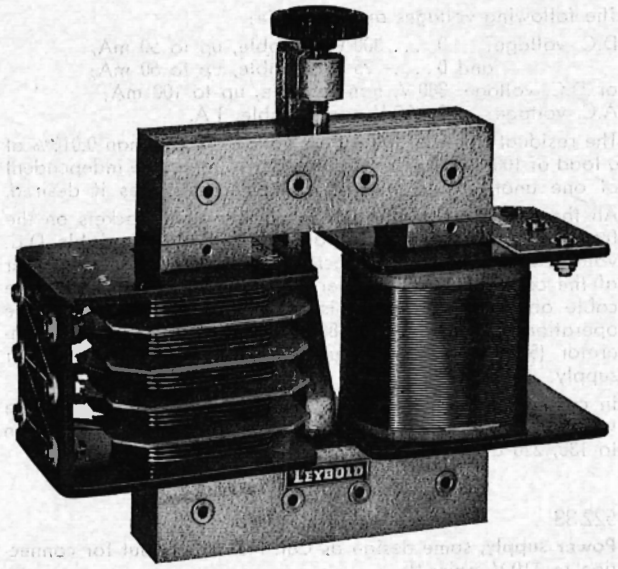
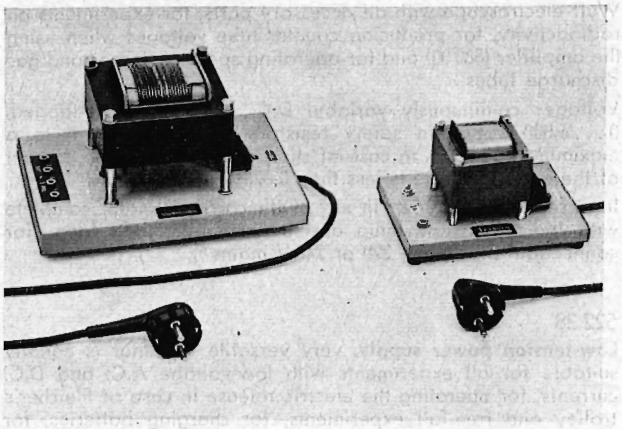
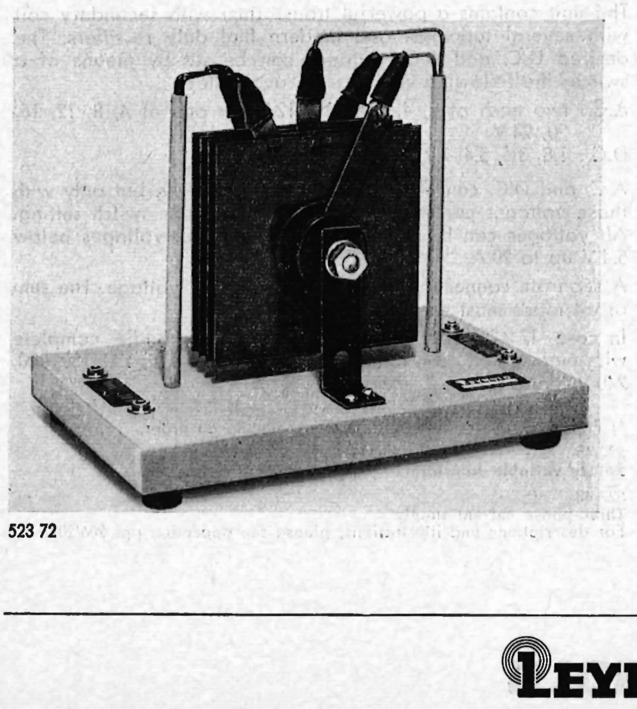


Fig. 75 PH 2045
Demountable demonstration transformer assembled from: U-core with yoke (562 11), clamping device (562 12), coil with 500 turns (562 14), and coil with 46 turns (562 18).



562 75 562 76



523 72

Demountable demonstration transformer

An instructive source of voltage that is truly versatile. It consists of a U-core with yoke and clamping device and interchangeable coils.

The individual parts are described on pp. 142–144.

On the primary side of the transformer, coils with 250, 500 or 1,000 turns can be used (Cat Nos. 562 13/14/21/15), and on the secondary side, coils having 46 to 23,000 turns. Figure 75 shows the coil with 46 turns which has 6 tappings enabling the voltage to be varied in steps. This coil can be loaded with 10 A for an unlimited period of time, and may even be short-circuited for a short time without suffering damage.

The following voltages can be derived from the 46 turns secondary coil (562 18):

Primary voltage	Primary coil	Secondary voltage	in steps of
110 V	250 turns 500 turns 1,000 turns	20 V 10 V 5 V	2 V 1 V 0.5 V
220 V	500 turns 1,000 turns	20 V 10 V	2 V 1 V

562 75

Transformer, 2 to 12 V, 100 W. Handy source of A.C. which may also be used together with a selenium dry rectifier to give a D.C. source, e.g. for charging accumulator batteries.

On wooden board, 15×21 cm², permanently wired, with 4 mm sockets at the output for tapping 2, 4, 6, 8, 10 and 12 V, can take loads of up to 10 A. The transformer can be adapted for connection to 110 or 220 V mains by changing the connections on the primary side; complete with mains cable.

562 76

Transformer, 6 V, 30 W, especially for operating a lamp (450 51). On wooden board, 15×10.5 cm², permanently wired, with two 4 mm output sockets. By changing the connections on a terminal strip the transformer can be adapted for connection to 110 or 220 V mains. Complete with mains cable.

523 71/72/73

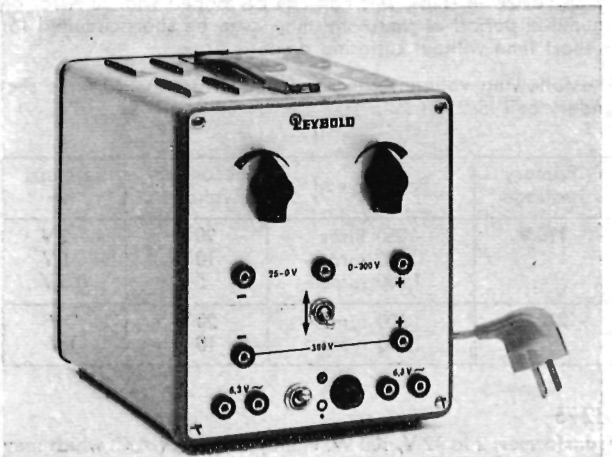
Rectifier elements, for rectifying A.C. voltages up to 20 V. These selenium full-wave rectifiers are a very popular source of D.C. for teaching because they have an indefinitely long life, do not require any maintenance and can be fed from any low-voltage transformer. The most suitable such transformer has been found to be the demountable demonstration transformer (see Fig. 75) with a 500 turns primary coil (at 220 V mains voltage) and a 46 turns secondary coil (562 11/12/14 or 21/18) from which 2 to 20 V can be derived in steps of 2 V. Each rectifier element consists of 4 selenium rectifier plates connected in the Grätz type bridge circuit, which are mounted on a base board. The connections are made in such a clear manner that the principle of full-wave rectification with four individual rectifiers can be explained with them. Output polarity and maximum continuous load are marked on the apparatus; input and output are each provided with one pair of 4 mm sockets. The maximum current stated refers to a continuous load and may be considerably exceeded temporarily.

Max. input voltage	20 V	20 V	20 V
Max. continuous current	6 A	10 A	20 A
Plate size mm²	100×62	100×100	100×200
Cat. No.	523 71	523 72	523 73

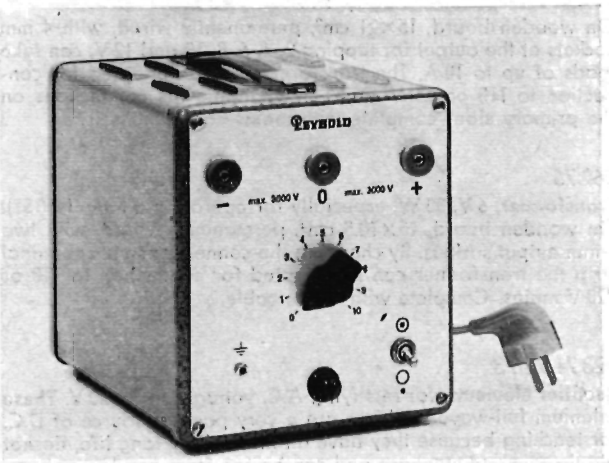
522 35

Power supply, for supplying electronic circuits with anode-, grid- and heating voltage, and for many other experiments in physics.

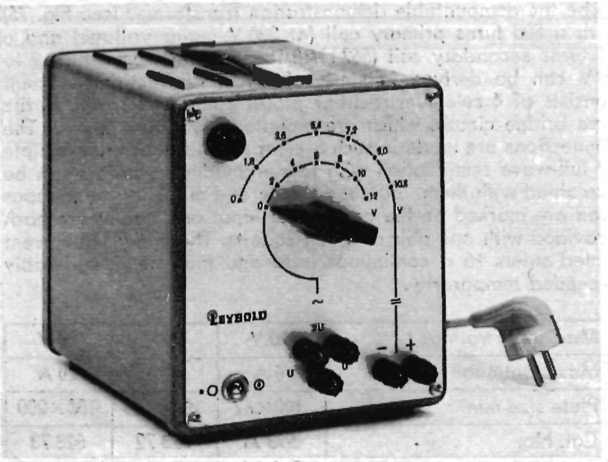
The D.C. voltages supplied by the unit are rendered hum-free by a liberally dimensioned filter. The D.C. side is entirely separate from the mains and can, therefore, be earthed at any desired point. The voltage regulation is effected by means of high-grade potentiometers which permit virtually continuous variation.



522 35/33



522 37



522 38

The following voltages are available:

D.C. voltage: 0 .... 300 V, variable, up to 50 mA,
and 0 .... 25 V, variable, up to 50 mA;
or D.C. voltage: 380 V, non-variable, up to 100 mA;
A.C. voltage: 2×6.3 V non-variable, 1 A.

The residual ripple of the output voltage is less than 0.010% at a load of 100 mA. The two alternating voltages are independent of one another and may be connected in series if desired.

All these voltages can be taken off the 4 mm sockets on the front panel. The heating voltages and the non-variable D.C. voltage are, moreover, connected to a six-pin socket in the rear of the casing and can be derived from there with a six-core cable and suitable plug. This facility is made use of in the operation of the amplifier (580 00) and the high-frequency generator (587 40), which are supplied without a built-in power supply.

In case, 17×22×20 cm³ in size, with carrier handle, complete with indicating lamp and mains cable, 2 m long; for connection to 130, 220 or 240 V *).

522 33

Power supply, same design as Cat. No. 522 35, but for connection to 110 V mains *).

522 37

High-tension power supply. This unit is a variable, well-smoothed source of D.C. for electrostatics experiments, for the Wulf electroscope with all accessory parts, for experiments on radioactivity, for producing counter tube voltages when using the amplifier (580 00) and for operating spectrum lamps and gas discharge tubes.

Voltage: continuously variable D.C. voltage, centre-tapped, 0 ... 6,000 V. Built-in safety resistors limit the current to a maximum of 2.5 mA in case of short-circuit. The ripple content of the output voltage is less than 0.025% at 1 mA load.

In case, 17×22×20 cm³ in size, with carrier handle, complete with indicator glow lamp and mains cable, 2 m long; for connection to 110, 130, 220 or 240 V mains *).

522 38

Low-tension power supply, very versatile unit that is equally suitable for all experiments with low-voltage A.C. and D.C. currents, for operating the electric release in case of Fletcher's trolley and free-fall experiments, for charging batteries, for operating induction coils. Particularly useful as current supply in practical work.

The unit contains a powerful transformer with secondary coil with several tappings, and modern high-duty rectifiers. The desired D.C. and A.C. voltages can be set by means of a switch; the following voltages are available:

A.C.: two each of 2, 4, 6, 8, 10, 12 V; or one of 4, 8, 12, 16, 20, 24 V.
D.C.: 1.8, 3.6, 5.4, 7.2, 9.0, 10.8 V.

A.C. and D.C. can be taken off simultaneously, but only with those voltages corresponding to any particular switch setting. All voltages can be loaded up to 10 A; D.C. voltages below 5.4 V up to 20 A.

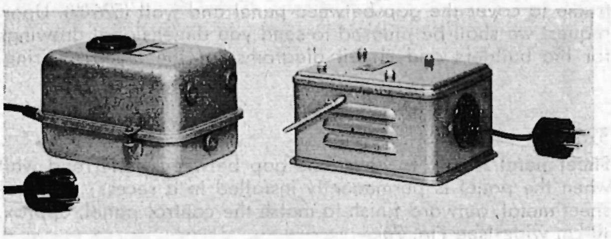
A separate connection supplies 6 V, 5 A A.C. voltage. The sum of all loads must not exceed 200 W.

In case, 17×22×20 cm³ in size, with carrier handle, complete with mains cable, 2 m long, for connection to 110, 130, 150, 220, 240 V mains *).

***) Please state available voltage when placing an order.**

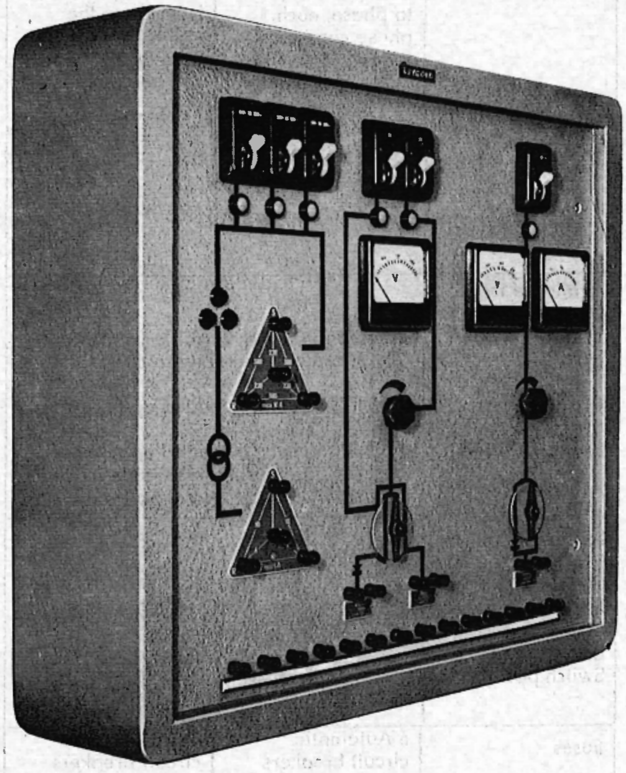
522 45
Rotary variable transformer (Ring-core auto-transformer)

522 48
Three-phase current supply
For descriptions and illustrations, please see appendix, pp. 206/207.



522 60 522 61

Control panels



526 00

526 00
Control panel for connection to three-phase current.

526 05
Control panel for connection to alternating current.

Our control panels can be permanently installed. These current supply units are designed for two different functions: to provide the voltages most commonly used in teaching and allow for sufficiently high loads, and to distribute these voltages in a manner as flexible as possible to the consumers, by means of permanently installed wiring. They contain the switches, fuses and measuring instruments necessary for these purposes.

Three-phase current is more suitable for these purposes, because heavy loads can be distributed better over three phases; moreover, three-phase current is very important in technology and therefore its treatment in teaching is of interest.

522 60
Magnetic voltage stabiliser for 220 V),** for stabilising voltage fluctuations in 220 V, 50 c/s A.C. mains. At a nominal load of 30 W, the unit will smooth out all mains voltage fluctuations up to ± 20% in the range of magnetic saturation, and the output voltage will not deviate by more than ± 1% from the nominal voltage, 220 V.

Particularly suitable for stabilising the input voltage of the high-tension power supply (522 37) if the high tension is to be used for the Geiger counter (546 28) or for measuring ionisation current with the ionisation chamber (546 25) and the measuring amplifier (532 01).

In metal case, 10.5×11.5×17 cm^3 in size, complete with three-core cable, 1.50 m long. Weight: 3.2 kp (kg wt).

**) Special designs for other mains voltages available on request.

522 61
Matching transformer, for matching electric apparatus to a mains voltage that is different from their operating voltage. This unit will transform an input voltage (mains voltage) of 110, 125, 220 or 240 V into an output voltage (operating voltage) of the same series, i.e. of 110, 125, 220, 240 V.

Maximum load: 150 W, frequency range: 50 to 60 c/s.

Dimensions: 12×16×10 cm^3, weight: 2.7 kp (kg wt).

Connection at the input: mains cable.

Connection at the output: Schuko socket (if required, please order Schuko plug additionally).

The input and output voltages can be changed by altering connections in the interior of the casing.

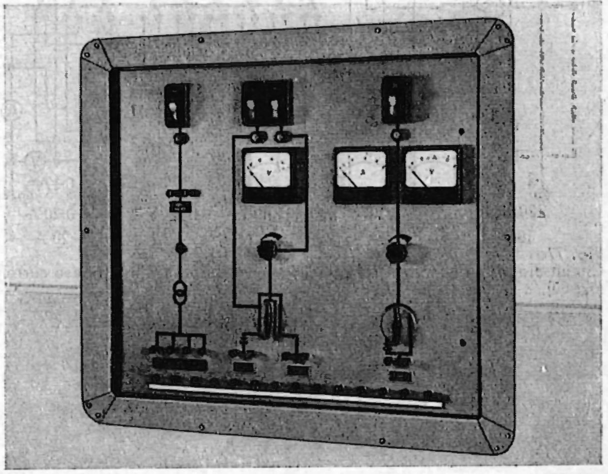


Fig. 76 PH 2046
A.C. control panel permanently installed in a recess in the wall and covered with frame (526 09).

We therefore recommend the installation of a three-phase current control panel (526 00) wherever local conditions permit this.

Both control panels (526 00 and 526 05) are clearly arranged and divided into three sections: one three-phase or alternating current section, for deriving mains voltage, one variable section for deriving variable D.C. and A.C. voltages of up to 220 V, and one low-voltage section for high-amperage, low-voltage A.C. and D.C. All voltages can be taken from output screw-terminals with 4 mm sockets.

Connection to the consumer points can be made by means of 14 consumer terminals, each of which is permanently connected to the bench wiring when the control panel is being installed.

The output terminals for the voltages and the consumer terminals are connected with flexible leads as required; in this manner each working place can be supplied with any one of the voltages available on the panel with a minimum of wiring.

Further features: combined switches and automatic fuses for switching on and off and as an overload protection, glow-lamps for indicating whether a particular line is on. Clearly visible symbols indicate the path of the current and explain the relations between the various elements and the function of the built-in measuring instruments. The variable voltages are produced by variable transformers which are very liberally dimensioned, as are the built-in rectifiers. All secondary circuits are electrically insulated from the primary mains voltage and can be earthed anywhere.

The control panels have the shape of a cabinet; the front panel swings out. Their interior is accessible without detaching screws or electric connections; a key for opening the front panel is supplied with them. The panels may be mounted on a wall, or in a recess; for this latter case we supply a sheet-metal frame to cover the gap between panel and wall (526 09). Upon request we shall be pleased to send you dimensional drawings for the builders and circuit diagrams for the electric wiring.

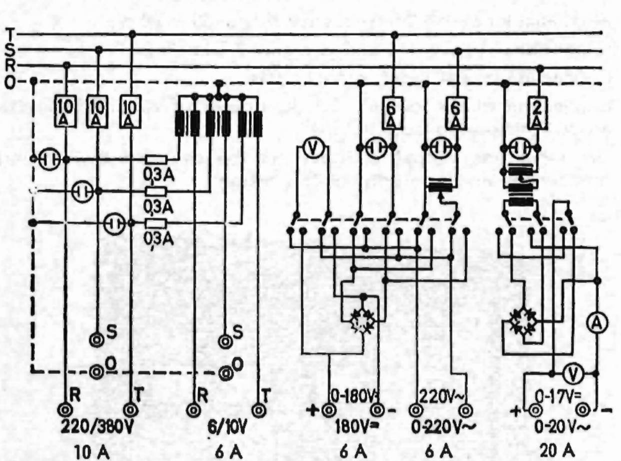


Fig. 77a
Circuit diagram of the control panel for connection to three-phase current (526 00).

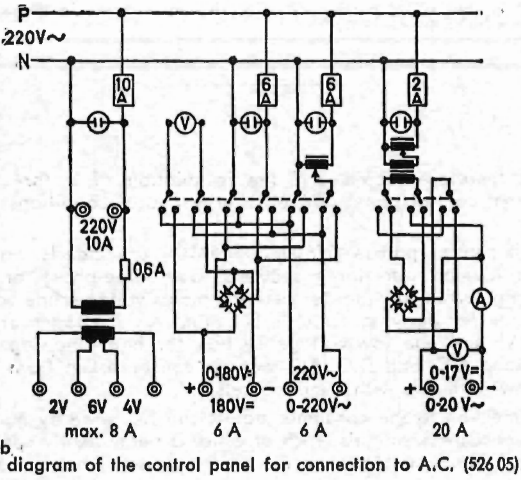


Fig. 77b
Circuit diagram of the control panel for connection to A.C. (526 05).

526 09

Sheet-metal frame, to cover the gap between panel and wall when the panel is permanently installed in a recess; made of sheet metal, outward finish to match the control panel, approx. 10 cm wide (see Fig. 76).

Technical data	Three-phase current control panel 526 00	A.C. control panel 526 05
Available from the three-phase current or from the A.C. section	Three-phase current in Y-connection 3×220 V phase to 0 and 3×380 V phase to phase, each phase can be loaded up to 10 A. Three-phase current in Y-connection 3×6 V phase to 0 and 3×10 V phase to phase, each phase can be loaded up to 6 A.	A.C., 220 V, can be loaded up to 10 A A.C. 2/6/4 V can be loaded up to 8 A, from these the voltages 2/4/6/8/10/12 V can be combined.
Available from variable section Switch position I or Switch position II	A.C. continuously variable from 0 to 220 V, can be loaded up to 6 A and D.C. 180 V, can be loaded up to 6 A A.C. 220 V, can be loaded up to 6 A, and D.C. continuously variable from 0 to 180 V, can be loaded up to 6 A	
Available from the low-voltage section Switch position I or Switch position II	A.C. continuously variable from 0 to 20 V, can be loaded up to 20 A D.C. continuously variable from 0 to 17 V, can be loaded up to 20 A	
Fuses	6 Automatic circuit breakers 3 Fuses	4 Automatic circuit breakers 1 Fuse
Consumer terminals	14	14
Meters (Moving iron instruments)	1 Voltmeter 0 to 250 V A.C./D.C. 1 Voltmeter 0 to 20 V A.C./D.C. 1 Ammeter 0 to 20 A A.C./D.C. Max. error 1.5% of f.s.d.	
Input power 1)	3-phase current 220/380 V per phase, can be loaded up to 16 A, with loadable neutral conductor	Alternating current 220 V; can be loaded up to 20 A
Dimensions 2)	980×855×235 mm³	
Weight	Approx. 73 kp (kg wt)	Approx. 70 kp (kg wt)

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1) In case of different mains voltages we recommend providing a series transformer (526 01 or 526 06) because all components of the panels have been designed for the above input voltages.

2) Dimensions for recessed fitting on request.

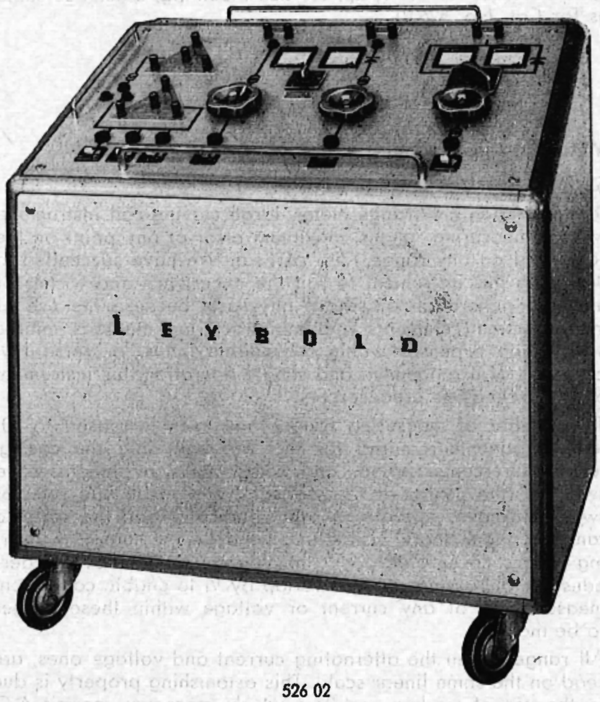
526 02

Control desk on wheels for connection to three-phase current

Control desks on wheels are control panels that can be wheeled up to the working bench, thus rendering permanently installed consumer wiring unnecessary. Such control desks are particularly suitable for modern class rooms in which no permanently fitted work benches are provided to leave the teacher free to suit the arrangement of the furniture to day-to-day experimental requirements. Again, they are easy to transport into another room, e.g. the preparation room, and all one has to do in order to have a ready-to-use control panel is to put a plug into one of the wall sockets.

The circuitry of the control desk is very similar to that of the control panels. It is likewise divided into three sections with 3-phase and alternating current, variable D.C. and A.C. and low-voltage heavy-current D.C. and A.C. The combined automatic circuit breakers are conveniently accessible at the lower edge of the slanting top of the desk and the passage of current is indicated on the top of the desk with painted-on symbols in a similar manner to that with the control panels. The desk top accommodates the adjusting knobs, meters, and consumer terminals. The control desks are also equipped with amply dimensioned variable transformers and selenium rectifiers. All variable circuits are electrically insulated from the primary voltage, and can be earthed.

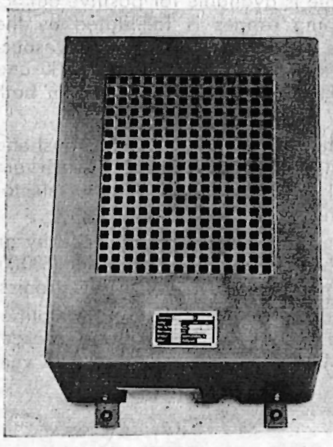
The control desk is housed in a solid metal case resting on 4 rubber-tyred wheels. It is connected to the electric mains by means of a 10 m long cable that winds up on a cable drum.



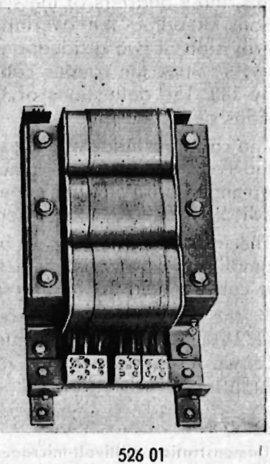
526 02

Technical data	Three-phase current control desk 526 02
Available from the three-phase current section	Three-phase current 3×220/380 V 10 A per phase Three-phase current 3×6/10 V, 6 A per phase
Available from the variable section	A.C. continuously variable from 0 to 250 V, 6 A D.C. continuously variable from 0 to 220 V, 6 A
Available from the low-voltage section, Switch position I	A.C. continuously variable from 0 to 20 V, 20 A
Switch position II	D.C. continuously variable from 0 to 17 V, 20 A
Fuses	6 Automatic circuit breakers 3 Fuses
Meters (moving iron instruments)	1 Voltmeter: 0–250 V, A.C./D.C. 1 Ammeter: 0– 6 A, A.C./D.C. 1 Voltmeter: 0– 25 V, A.C./D.C. 1 Ammeter: 0– 25 A, A.C./D.C. Max. error 1.5% of f.s.d.
Power requirements (wall socket) [1]	Three-phase current: 220/380 V, 16 A per phase, with loadable neutral conductor
Dimensions	81×90×90 cm³
Weight	Approx. 175 kp (kg wt)

[1] If different mains voltages only are available we recommend providing a series transformer (e.g. Cat. No. 526 01), because all components of the control desk have been designed for this input voltage.



526 01
(with perforated metal case)



526 01
(perforated metal case removed)

526 01

Transformer, for use when connecting control panel 526 00 or control desk 526 02 to three-phase current mains of 110/125/150 V. Maximum output 10 kW.

In perforated sheet-metal case, suitable for wall mounting, weight approx. 60 kp (kg wt) with terminal strip with solder tags for various mains voltages.

526 06 **(not shown, similar to 526 01)**

Transformer, for use when connecting control panel (526 05) to A.C. mains carrying 110/125/150 V, maximum output 4.6 kW.

In perforated sheet-metal case; suitable for wall mounting, with terminal strip with solder tags for various mains voltages; weight approx. 38 kp (kg wt).

Transformers for connecting the control panels to other mains voltages can be manufactured on special order. Please specify available mains voltage exactly.

526 08 (not shown)

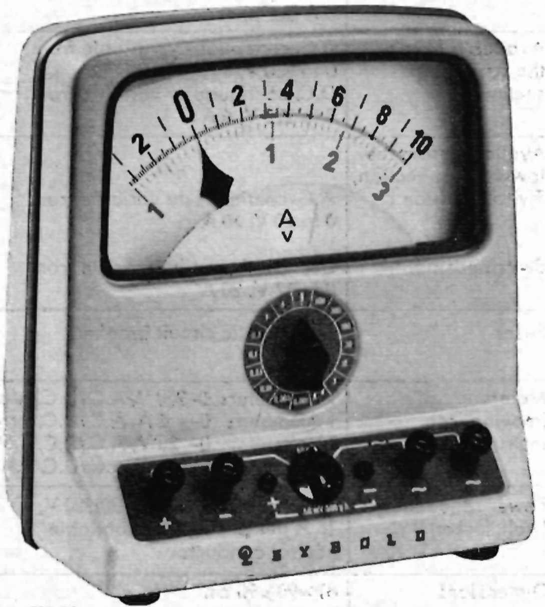
Resistor for arc lamps, 25 Ω; can be loaded up to 6 A. Suitable as series resistor when the arc lamp (442 32) is to be operated with D.C. from one of the control panels (526 00 or 526 05) or from the control desk (526 02). The resistor should preferably be mounted on the wall beside the control panel and permanently wired. The input terminals should be connected to the 180 V D.C. terminals of the control panel and one or more of the 5-pole sockets (526 10 or 526 11) should be provided at the output. In perforated metal case, with shockproof insulation, weight approx. 4.7 kp (kg wt).

For other details see p. 83.

BOGENLAMPE

526 10

526 11



531 86

Technical data:

Full scale deflection: 300 µA (at 60 mV), maximum error at any point on the scale 1.5% of f.s.d.

Further measuring ranges:
D.C. current: 0.001; 0.003; 0.01; 0.03; 0.1; 0.3; 1; 6 A.
D.C. voltage: 3; 10; 30; 100; 300; 600 V.
A.C. current: The same ranges as for D.C.
A.C. voltage: The same ranges as for D.C. voltage.

Scale: Zero point in the left half, length of scale approx. 20 cm, with two graduations: black –30 to +100; red –10 to +30.

Terminals: One pair of terminals with 4 mm sockets for "D.C." and one pair for "A.C." and D.C./A.C. switch.
One pair of 4 mm sockets for direct connection to the movement.

Casing: 30×30×16 cm³, made of grey shatter-proof plastic, dust-tight, antistatically treated, with rubber feet.

Weight: Approx. 3.5 kp (kg wt).

526 10

Special socket for arc lamp, flush mounting; 5-pole socket for convenient connection of the arc lamp if the arc voltage is derived from one of the control panels (e.g. 526 00 or 526 05) or from the control desk (526 02) and passed through resistor (526 08). The socket has the following connections:

Arc voltage, voltage for the automatic feed accessory, and earth line.

526 11

Special socket for arc lamp, surface mounting, otherwise same as for Cat. No. 526 10.

Measuring instruments

531 86

Demonstration multirange meter, large moving-coil instrument, with 30 measuring ranges, maximum error at any point on the scale and on any range 1.5% of f.s.d. We have succeeded in designing this instrument to suit the experience and wishes of a whole generation of school physicists because the use of modern circuit elements and manufacturing methods enable us to keep expenses within reasonable limits. In versatility, clearness of arrangement and simple operation this instrument by far exceeds its predecessors.

The number of measuring ranges has been increased to 30; the components required for this are built into the casing, temperature-compensated, and selection is by means of a switch at the centre of the vertical front panel. The selector switch moreover operates a range indicator and the selected range appears clearly visible in a window. The current-measuring ranges cover 4 decades; the voltage ranges cover 5 decades. Neighbouring ranges overlap by ⅓ to enable convenient measurement of any current or voltage within these ranges to be made.

All ranges, even the alternating current and voltage ones, are read on the same linear scale. This astonishing property is due to the use of modern rectifiers which, moreover, permit A.C. measurements at frequencies of up to 50 kc/s.

The zero point is in the left half of the scale; this permits measuring currents and voltages of either polarity, yet, despite this, three-quarters of the scale is available for positive deflections. Reading the overlapping ranges is facilitated by the provision of two graduations with 30 and 100 divisions, respectively, since the ranges can be divided alternately by 30 and by 100. The deflections of the pointer can be read from **both** sides of the meter.

The casing is made of grey shatter-proof plastic and is dust and moisture tight. All terminals and the A.C./D.C. switch are arranged on a sloping panel at the bottom. The range selector switch is located above them.

The instrument may either be used directly, or preceded by an amplifier: when used with the low-frequency amplifier (580 00) it can be used for measurements in acoustics and electronics.

If the instrument is preceded by the measuring amplifier (532 01) very small currents (down to 10–12 A) and charges (down to 3×10^{-9} As) and voltages can be measured with very high input resistance.

531 87

Demonstration millivolt-microammeter

For description and illustration, please see appendix, p. 207

442 73

Twin moving-coil instrument; zero point in the left half, suitable for projection. Moving-coil instrument with two separate movements suitable for projection with the Leitz projectors PRADO, "pradovit", or other projection arrangements. With this instrument two electric measurements can be rendered visible to large audiences simultaneously, e.g. when making measurements on Ohm's law, Kirchhoff's laws, Joule's law, the charge-to-mass ratio of an electron *e/m*, Planck's constant *h* and many others.

Additional measuring ranges can be obtained by using a range control box (one for each movement, 442 74) which provides 24 additional ranges and is sufficient to cover all the usual measurements. The instrument can also be used as indicating instrument for the measuring amplifier (532 01).

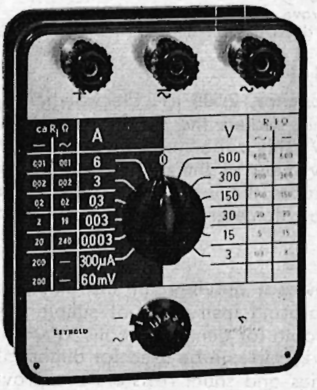
Technical data (these apply to both movements):

Full deflection:	300 µA (at 60 mV)
Maximum error at any point on the scale: 1% of f.s.d.	
Graduation:	–5 to +30
Additional ranges:	By the use of one range control box per movement (442 74).
Connections:	Coaxial plugs with cables, 2 m long.
Casing:	Approx. 16×5×6 cm³, with stand rod, dia. 12 mm, and guide rail for mounting on Leitz Projectors PRADO and "pradovit".

2 coaxial cables are supplied with the instrument.

Range control boxes must be ordered separately.

442 73



442 74

The instrument has been specially designed for mounting on the Leitz projectors PRADO and "pradovit". This method of projection is suitable even for large lecture halls, without necessitating darkening of the room.

However, the instrument can also be projected from an optical bench using standard optical parts (see Fig. 78). If in doubt whether the instrument can be used with your own projector (other than Leitz-PRADO or "pradovit") please write to us for dimensional drawings of the instrument.

442 74

Range control box for twin moving-coil instrument (442 73), with 24 current and voltage measuring ranges, one with a direct input for the movement. The ranges are very clearly arranged: the current measuring ranges are on the left against a black background and the voltage measuring ranges on the right against a white background; in addition, the internal resistances are stated on the front panel. The desired range can be set by turning the range control switch and the kind of current by operating the D.C./A.C. switch.

The ranges have been so chosen that practically all voltages and currents the measurement of which may be desired in teaching can be covered, and comprise:

Direct connection to movement: 300 µA (60 mV)

D.C. current:	0.003; 0.03; 0.3; 3; 6 A
D.C. voltage:	3; 15; 30; 150; 300; 600 V
A.C. current:	The same ranges as for D.C.
A.C. voltage:	The same ranges as for D.C.
Max. error at any point on the scale:	1% of f.s.d.

In box, approx. 13×5×11 cm³, with etched front panel, range control switch and A.C./D.C. switch, three input terminals with 4 mm sockets for A.C. and D.C. and two 4 mm sockets for making direct connections to the movement. The output socket is a coaxial socket fitting the coaxial cable of the instrument.

We recommend obtaining two range control boxes to permit independent use of the ranges of both instruments that are combined in the twin moving-coil instrument.

442 83
Twin moving-coil instrument; zero point at the centre
442 84
Range control box for 442 83
For descriptions and illustrations, please see appendix, p. 206.

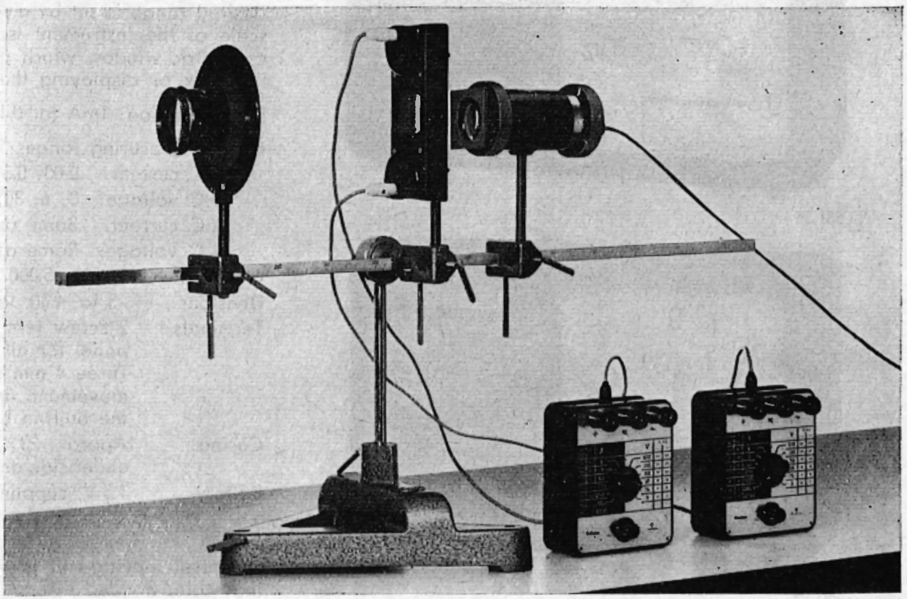


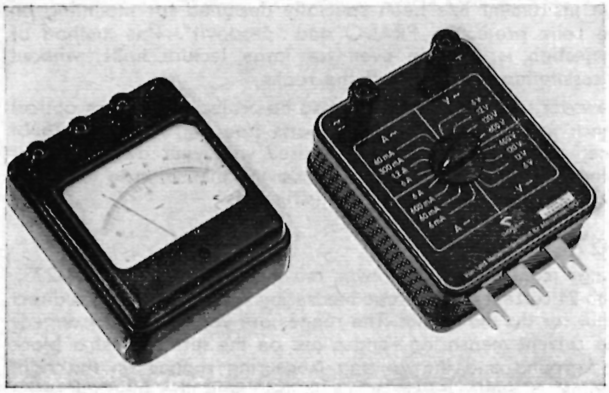
Fig. 78

PH 2047

Fig. 78
Twin moving-coil instrument (442 73) in a projection arrangement on the small optical bench (460 41/42). The two movements are each provided with a range control box (442 74).

For this arrangement, we recommend:

1 Small optical bench	460 41
1 Lamp house	450 60
1 Lamp, 6 V, 30 W	450 51
1 Double-lens condenser	460 19
1 Projection objective	460 13
3 Leybold bosses	301 01



531 51 531 57

Separate resistors for mavometer (531 51), can be supplied for the following ranges for special purposes:

Shunts for: 3/6/12/30/60/120/300/600 mA; 1.2/3/6/12 A

Series resistors for: 3/6/12/30/60/120/300/600 V

These can be used for D.C. and A.C. and can be clamped to the connecting sockets of the instrument.

538 31

LEYBOLD
0
1
2
3

531 55

LEYBOLD
2
1
0
1
2
3

531 56

531 51

Mavometer WG, a convenient moving-coil instrument of good accuracy which we recommend for preparation work and practical work. The instrument has an A.C./D.C. switch with built-in rectifier. Any series and shunt resistors connected to it can, therefore, be used for both kinds of current. When used together with range control box (531 57) the instrument represents a universal multirange instrument:

Full scale deflection: 2 mA (100 mV) D.C.; 2 mA (1.5 V) A.C.

Max. errors at any point of scale: 1% of f.s.d. for D.C.; 1.5% of f.s.d. for A.C.

Scale: –10 to +60, length of scale 81 mm, with mirror and knife-edge pointer.

Further ranges: By connecting range control box (531 57).

Terminals: 3 screw terminals with 4 mm sockets.

Casing: $13.6\times11.5\times6.6\ cm^3$

531 57

Range control box for mavometer (531 51).

Ranges:

D.C. current: 0.006; 0.06; 0.6; 6 A

D.C. voltage: 6; 12; 120; 600 V

A.C. current: 0.06; 0.3; 1.2; 6 A

A.C. voltage: 6; 12; 120; 600 V

In case, $14\times12\times5\ cm^3$, with selector switch. Switchover from D.C. to A.C. ranges and vice versa is done by operating the D.C./A.C. switch of the mavometer.

531 59

Metravo multi-meter

For description and illustration, please see appendix, p. 208.

538 31

Capacitor, 2,500 µF. Electrolytic capacitor on base, with two 4 mm sockets the polarity of which is marked; maximum p.d. 12 V. This capacitor can be connected to the terminals of the movement of the demonstration multirange meter in order to increase the integrating time-constant when the meter is used in a ratemeter circuit, thus producing a steadier reading.

531 55

Universal moving-coil instrument, zero point on the left. A measuring instrument of simpler design, which is particularly suitable for demonstrations to smaller classes and for practical work, and can be used for almost all problems occurring there. Series and shunt resistors are provided inside the casing. The desired range is set by means of a range selector switch. The scale of the instrument is double-sided and is broken by a concentric window which permits reading the instrument from the back or displaying the deflections in shadow projection.

Full deflection: 1mA (at 0.1 V)

Further measuring ranges:

D.C. current: 0.03; 0.3; 1.5; 6 A

D.C. voltage: 3; 6; 30; 300 V

A.C. current: Same as for D.C.

A.C. voltage: Same as for D.C.

Ohm scale: 0; 500; 5,000 Ω; with built-in battery

Divisions: –5 to +30, length of arc approx. 10 cm.

Terminals: 2 screw terminals with 4 mm plug on the front panel for all ranges. Three 4 mm sockets for direct connection to the movement and for measuring resistances with the built-in battery.

Casing: Approx. $23\times15\times7\ cm^3$, with rubber feet on the under side and back for horizontal or upright use.

Battery: 1.5 V, supplied with one battery inserted.

531 56

Universal moving-coil instrument, zero point at the centre of the scale, divided –30 to +30, otherwise same as for 531 55.

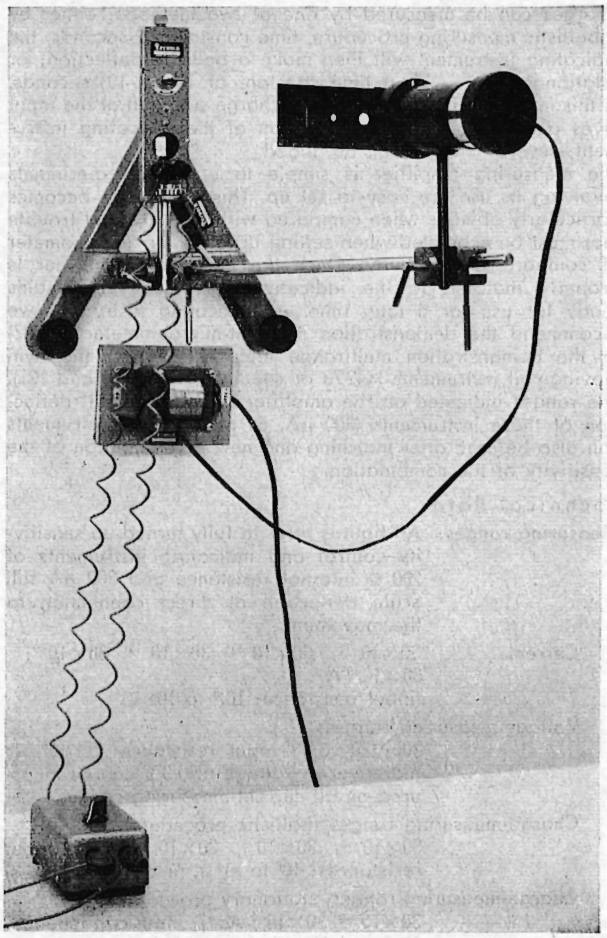


Fig. 79 PH 2048

532 10

School mirror galvanometer. Universal instrument suited to the requirements of teaching that is equally suitable for measuring currents in high-resistance systems and voltages in low-resistance systems, and for ballistic measurements*).

The moving coil of the galvanometer is suspended on a tensioned strip inside a soft-iron ring, and cored by a transversely magnetised, cylindrical magnet, thus making it sturdy and less sensitive to shocks. Its concave mirror is large and produces a bright spot of light that is clearly visible even in daylight.

Technical data:

Current sensitivity:	approx. 10^{-8} A/mm/m
Voltage sensitivity	approx. 3×10^{-7} V/mm/m
Ballistic current sensitivity:	approx. 10^{-8} As/mm/m **)
Internal resistance:	approx. 30 Ω
Critical external damping resistance:	approx. 300 Ω
Period of oscillation:	approx. 10 s
Concave mirror for the light-spot:	f = 35 mm, 10×20 mm²
Terminals:	two 4 mm sockets

Complete with circular level, locking lever and knob for adjusting the tension of the strip, with stand base; mounted on 12 mm dia. stand rod.

A tag with all electric data is supplied with the galvanometer. Without illuminating device and sensitivity regulator.

*) cf. "LEYBOLD Physics Leaflets", DC 537.741.5; c and d

**) As ≡ ampere-second ≡ coulomb.

532 11

Sensitivity regulator for the school mirror galvanometer. A combination of resistors for adjusting the external critical damping resistance between 100 and 350 Ω by means of a screw potentiometer, and varying the sensitivity by means of a potentiometer with rotary knob. A short-circuit loop provided on the side of the casing is for use with sources of current with low internal resistance, when the sensitivity regulator, source of current and galvanometer must be connected in series, and enables the external critical damping resistance to be adjusted in this case as well.

In case, 7×12×5 cm³ in size, with 4 mm sockets at the input and at the output.

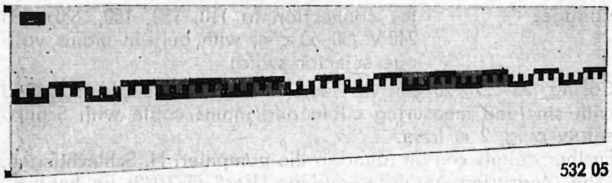
School mirror galvanometer with illuminating device and sensitivity regulator

For permanent mounting on a solid wall, we recommend using the following parts:

1	Stand base, length of sides 28 cm	300 01
1	Pair of levelling screws	300 06
2	Leybold bosses	301 01
1	Stand rod, bent, 60 cm long	300 52
1	Lamp-house	450 60
1	Lamp, 6 V, 30 W	450 51
1	Single-lens condenser with aperture attachment	460 17
1	Transformer, 6 V, 30 W	562 76

For permanent mounting in a recess of the wall, at least 60 cm wide, 38 cm high and 24 cm deep:

1	Stand base, length of sides 28 cm	300 01
1	Pair of levelling screws	300 06
1	Stand rod, 25 cm long	300 41
1	Stand rod, 50 cm long	300 42
3	Leybold bosses	301 01
1	Rotary clamp (double boss)	301 03
1	Right-angled prism	465 47
1	Prism table	460 25
1	Lamp-house	450 60
1	Lamp, 6 V, 30 W	450 51
1	Single-lens condenser with aperture attachment	460 17
1	Transformer, 6 V, 30 W	562 76

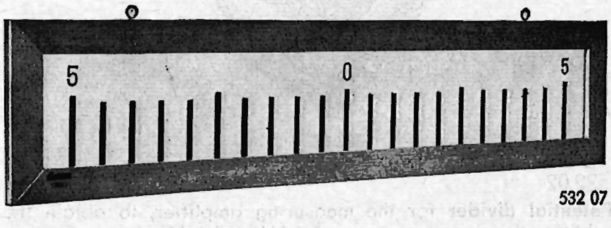


532 05

532 05

Scale for light-spot reading, on white, varnished sheet-metal, upper and lower edge beaded, 100×20 cm² in size, with clearly visible, coloured centimetre divisions, without numbers. The upper edge of the scale has holes for attaching rollers.

We recommend ordering two or three such scales and suspending them end-to-end on a curtain rail. This gives a continuous scale of sufficient length on a white background, on which the light spot may be produced, and which can be displaced for fine adjustment of the zero point.



532 07

532 07

Scale on glass in wooden frame. Frosted glass scale for light-spot reading, can be read from both sides, also suitable for use in undarkened rooms.

Glass plate, 100×26 cm² in size, with numbered black divisions spaced 5 cm apart, in wooden frame, with screw eyes for suspension.

532 01

Measuring amplifier, according to Inderthal and Gestrich (German Patent No. 1.117.651); D.C. amplifier for measuring currents, voltages and charges using a low-resistance moving-coil instrument as indicating instrument. The amplifier has a very high input resistance.

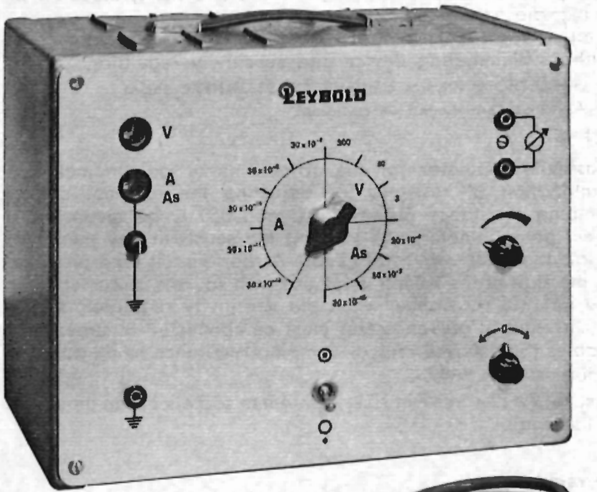
This apparatus is suitable

for measuring currents from current sources of high internal resistance, such as ionisation chambers, photocells and electron tubes;

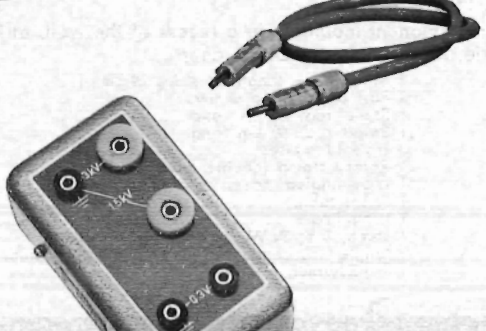
for use as an electrometer for measuring voltages in electronic circuits, in an electrolytic trough, in an electric field, across capacitors and electrolytic cells;

for measuring charges on parallel plate capacitors and other bodies when doing experiments on electrostatic induction or measuring short time intervals;

and for determining capacitances and resistances by a combination of measurements.



532 01



532 02

532 02

Potential divider for the measuring amplifier, to obtain the additional measuring ranges 1,5 kV and 3 kV, for series connection to the amplifier input.
The input resistances will then be 1×10^8 and 2×10^8 Ω respectively.
In metal case, $7\times12\times5$ cm³ in size, with 2 highly insulated sockets for the connection of the potential to be measured, one earthing socket and two output sockets, which must be connected to the input of the measuring amplifier.

Charges can be measured by one of two methods: either by a ballistic measuring procedure, time constant 0.2 seconds, the indicating instrument will then make a ballistic deflection; or "stationary", i.e. with a time constant of 10^4 to 10^5 seconds. In this method of measurement the charge supplied at the input gives rise to a stationary deflection of the indicating instrument; several charges can be added.
The measuring amplifier is simple to use and experiments involving its use are easy to set up. This advantage becomes particularly obvious when compared with the care and trouble that must be expended when setting up a mirror galvanometer of comparable sensitivity. Once the measuring amplifier is properly matched to the indicating instrument, it remains ready for use for a long time. As indicating instrument we recommend the demonstration millivolt-microammeter (531 87) or the demonstration multirange meter (531 86) or the twin moving-coil instruments (442 73 or 442 83; see pp. 103 and 121). The ranges indicated on the amplifier refer to the full deflection of these instruments (300 μA, 60 mV). Other instruments can also be used after matching and new determination of the sensitivity of the combination.

Technical data:

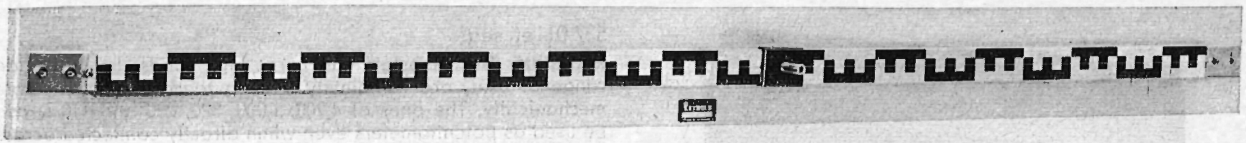
Measuring ranges:	All figures refer to fully turned-up sensitivity control and indicating instruments of 200 Ω internal resistance and 300 μA full scale deflection at direct connection to the movement.
Current:	30×10^{-12}; 30×10^{-11}; 30×10^{-10}; 30×10^{-9}; 30×10^{-8} A; (input resistance: 10^{10} to 10^6 Ω)
Voltage-measuring ranges:	300; 30; 3 V; input resistance: 5×10^8 Ω; moreover, a voltage of 0.3 V can be measured on all current-measuring ranges.
Charge-measuring ranges (ballistic procedure):	30×10^{-10}, 30×10^{-9}, 30×10^{-8} As*); (input resistances: 10^8 to 10^6 Ω, time constant 0.2 s)
Charge-measuring ranges, stationary procedure:	30×10^{-10}, 30×10^{-9} As*); input capacitance: 10^{-8} and 10^{-7} F; respectively: time constant: approx. 10^5 and 10^4 s, respectively
Input terminals:	one coaxial socket for voltage determinations and one for current and charge measurements; a fitting, shielded coaxial cable is supplied with the amplifier.
Output terminals:	two 4 mm sockets
Front panel equipped with:	Input terminals, earthing button for the input, earth socket, range selector switch, output terminals, sensitivity control, set-zero control, on-off switch, screw-driver matching potentiometer
Voltage:	for connection to 110, 130, 150, 220, and 240 V (50–60 c/s), with built-in mains voltage selector switch

Casing, $33\times27\times20$ cm³ in size, with carrier handle, supplied with shielded measuring cable and mains cable with Schuko safety plug, 2 m long.
Further details can be found in the pamphlet: H. Schlechtingen, "The Measuring Amplifier and its Uses" (532 042) (in English).

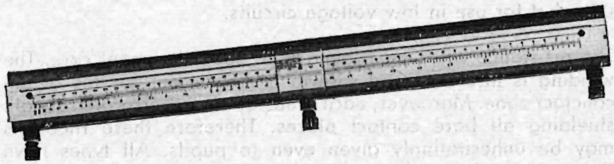
*) As ≡ ampere-second ≡ coulomb

532 042

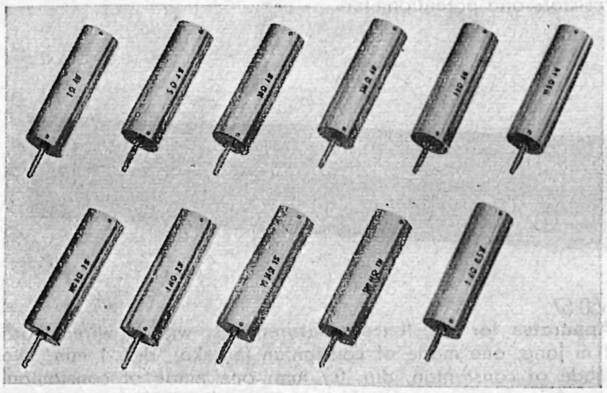
Pamphlet: H. Schlechtingen,
"The Measuring Amplifier and its Uses"
Besides a detailed description of the apparatus and information about measuring principle, circuit and accuracy of measurement, this pamphlet contains examples of experiments from various fields of physics, especially electrostatics and atomic physics, with a list of the required apparatus, circuit diagrams, assembly diagrams and special notes. One copy of this pamphlet is supplied with each measuring amplifier.



536 02

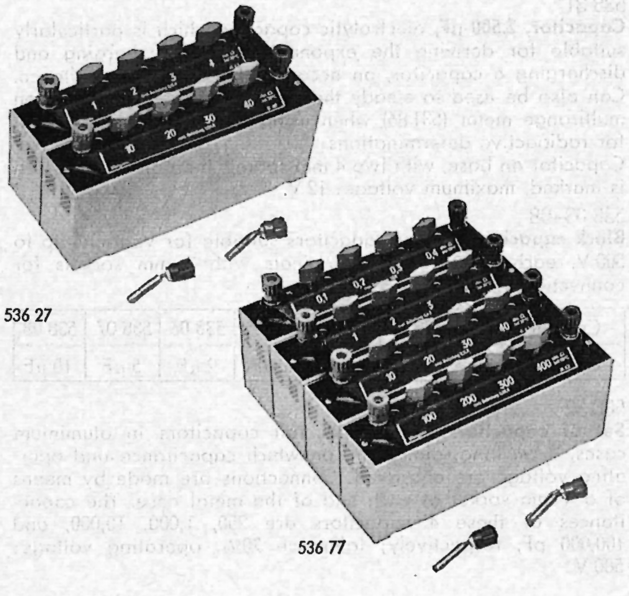


536 03



536 10/11/12/13/14/19/20/21/22/23/25

536 10 et seq.
Measuring resistors. Easily recognisable resistors that are very convenient to connect in series, and can be used for many experiments, such as Kirchhoff's rules, bridge resistance in measuring bridges, voltage dividers and the like.
Each resistor is contained inside a 9 cm long aluminium cylinder of 30 mm diameter on which the resistance in ohms and the maximum dissipation are engraved. Connections are made by means of a 4 mm plug at one end and a 4 mm socket at the other.
The measuring resistors from 1 Ω to 10,000 Ω are all wire resistors; the ones from 100,000 Ω to 1,000 MΩ artificially aged layered resistors, and in the case of these latter, limitation of the load and of the duration of the experiment are important.



536 27

536 77

536 02
Demonstration bridge, for demonstrating the principle of measuring resistances in a bridge circuit. The measurements can be watched from some distance away, because the apparatus is equipped with a clearly visible coloured scale. The measuring wire is made of constantan (eureka), 1 m long, 0.5 mm thick, and soldered to contact plates with two 4 mm sockets each at either end.
The scale is 1 m long with black, white and red divisions: both sides are grooved and the sprung brass slider with the sliding contact slides in these grooves. The slider is also provided with a 4 mm connecting socket.
The parts are mounted on a strong base board 110×9 cm² in size. For measurements we recommend using the measuring resistors 536 10 et seq. or the resistance boxes 536 27 and 536 77. As null-point indicator the demonstration multirange meter (531 86) is suitable.

536 03
Measuring bridge, for measuring resistance in bridge circuits; especially recommended for use in students' practical work. The instrument has a 50 cm long calibrated slide wire made of a special alloy and having a resistance of 7 Ω, and a scale with millimetre and ohm divisions. The sprung sliding contact is easy to move and the engraved mark on the slider permits exact reading of the values to which the slider has been set. Mounted on base board, approx. 55×9×5 cm³ in size, with rubber feet and three screw terminals with 4 mm sockets for connection.

Cat. No.	Resistance	Tolerance	Power
536 10	1 Ω	2%	4 W
536 11	5 Ω	2%	4 W
536 12	10 Ω	2%	4 W
536 13	100 Ω	2%	4 W
536 14	1,000 Ω	2%	4 W
536 19	10,000 Ω	2%	4 W
536 25	100,000 Ω	2%	2 W
536 20	1 MΩ	1%	2 W
536 21	10 MΩ	1%	1 W
536 22	100 MΩ	2%	1 W
536 23	1,000 MΩ	10%	0.5 W

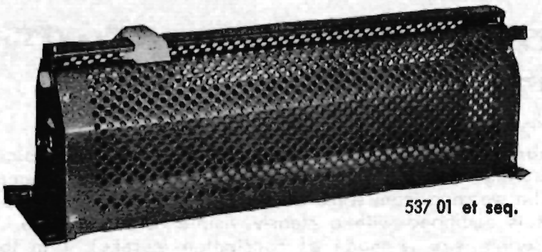
536 27
Resistance box, 1 to 110 Ω; same design as 536 77, but with only 2 rows of resistors, featuring a total number of 8 resistors.

In plastic box, 23×11 cm², height with plugs 14.5 cm; with 4 screw terminals with 4 mm sockets and 2 intermediate-connection plugs.

536 77
Resistance box, 0.1 to 1,111 Ω; maximum errors 0.2%; a set of low-inductance, low-capacitance resistors, suitable for exact D.C. and A.C. measurements even in the audio-frequency range. 16 separate resistors are arranged in 4 rows and can be combined by drawing out and inserting plugs. The contact pressure of these tapered plugs is so great that the resistance of one row with plugs inserted is only about 2×10^{-4} Ω. With this box any resistance between 0.1 Ω and 1,111 Ω can be set up and varied in steps of 0.1 Ω, the resistances in each row being in the ratio 1:2:3:4, whereas the resistances of the individual complete rows are in the ratio 1:10:100:1,000.

The resistors 0.1 to 0.4 Ω can be loaded up to 1.2 A, those from 1 to 4 Ω up to 0.4 A, those from 10 to 40 Ω up to 0.12 A and those from 100 to 400 Ω up to 0.04 A.

In plastic case, 23×21.5 cm², height with plugs in position 14.5 cm; with 8 screw terminals with 4 mm sockets, and 2 intermediate-connection plugs.



537 01 et seq.

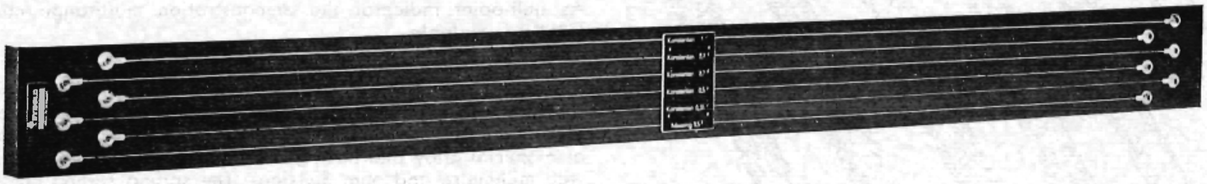
Rheostats

Ω	4,200	1,000	320	230	110	50	11
Max. current	0.3 A	0.6 A	1.5 A	1.5 A	2.5 A	5 A	8 A
Ap. length cm	40	30	40	40	40	50	40
Cat. No.	537 01	537 22	537 23	537 18	537 24	537 25	537 26

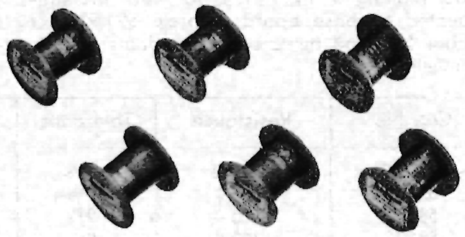
537 01 et seq.

Rheostats. The rheostats can carry high loads, have a wide range of uses, are completely safe to touch and very stable mechanically. The ones of 4,200, 1,000, 320, 230 and 110 Ω can be used as potentiometers even when directly connected across the 220 or 240 V mains. The low-resistance ones are primarily intended for use in low voltage circuits.

The resistance wires are wound on a special cement core. The winding is insulated and safe to touch, except for the actual conctact zone. Moreover, each rheostat has a perforated sheath shielding all bare contact places. Therefore these rheostats may be unhesitatingly given even to pupils. All types have three connecting points equipped with screw terminals with 4 mm sockets enabling them to be used as resistors, variable resistors and potentiometers.



550 57



550 59

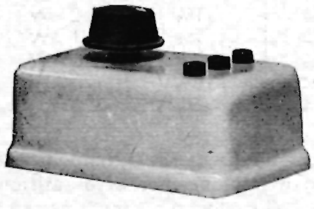
550 57

Apparatus for resistance measurements, with 6 wires, each 1 m long, one made of constantan (eureka), dia. 1 mm; two made of constantan, dia. 0.7 mm; one made of constantan, dia. 0.5 mm; one made of constantan, dia. 0.35 mm; and one made of brass, dia. 0.5 mm. The wires are stretched beside one another on a strong wooden board and end in 4 mm sockets at either end.

550 59

Set of 6 wires for resistance measurements, consisting of: constantan (eureka), dia. 0.35, 0.5, 0.7 mm; nichrome, dia. 0.5 mm; brass, dia. 0.5 mm; and iron, dia. 0.22 mm.

The wires are wound on reels (each reel holds approx. 10 m; in the cases of constantan, dia. 0.35 mm and iron, dia. 0.22 mm, however, each reel holds 20 m, and suitable lengths of wires are cut off from them for the experiments.



537 85

538 31

537 85

Rotary potentiometer, 100 kΩ, 0.5 W, especially suitable for use with batteries. Plastic case with rotary knob and three 4 mm connecting sockets.

538 31

Capacitor, 2,500 µF, electrolytic capacitor which is particularly suitable for deriving the exponential law of charging and discharging a capacitor, on account of its large capacitance. Can also be used to steady the reading of the demonstration multirange meter (531 86) when using it in a ratemeter circuit for radioactive determinations.

Capacitor on base, with two 4 mm sockets the polarity of which is marked, maximum voltage: 12 V.

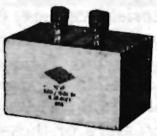
538 03

538 04

538 05

538 06

538 07

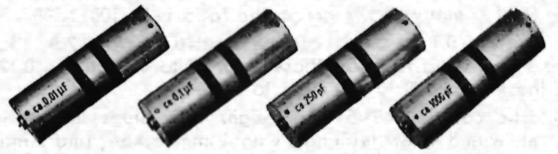


538 08

538 03–08

Block capacitors, paper capacitors suitable for voltages up to 500 V, each with 2 screw terminals with 4 mm sockets for connection.

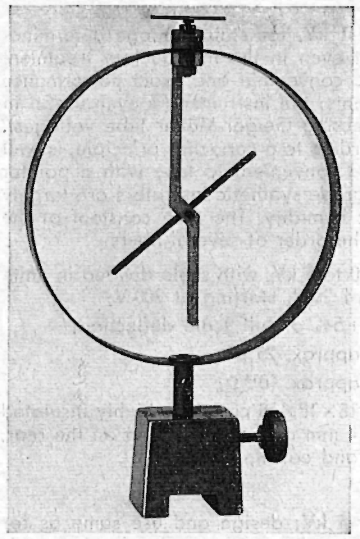
Cat. No.	538 03	538 04	538 05	538 06	538 07	538 08
Capacitance:	0.1 µF	0.5 µF	1 µF	2 µF	5 µF	10 µF



580 32

580 32

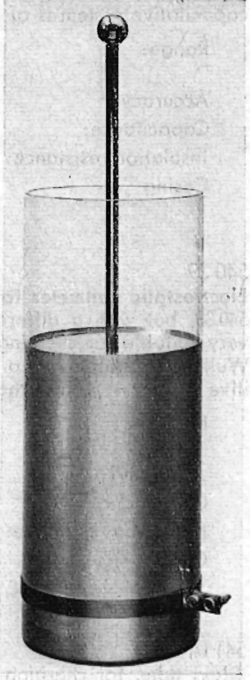
Set of capacitors; four metal foil capacitors in aluminium cases, 9 cm long, dia. 3 cm, on which capacitance and operating voltage are engraved. Connections are made by means of a 4 mm socket at each end of the metal case. The capacitances of these 4 capacitors are 250, 1,000, 10,000, and 100,000 pF, respectively; tolerance 20%, operating voltage: 500 V.



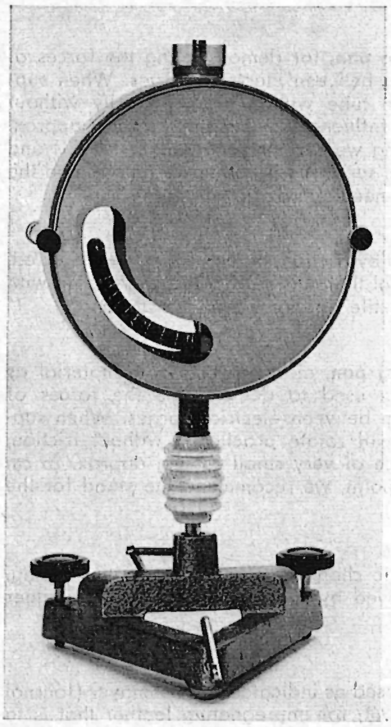
540 09

LEYBOLD
538 82
MADE IN GERMANY
5000 pF
3000 / 5000 V

538 82



544 02



540 37

540 52

Electrostatics

544 02
Leyden jar, high-tension capacitor for electrostatics experiments, and for use in high-frequency Tesla oscillating circuits. In this design, connection to the outer metal coat is easy to make because a metal ring with 4 mm socket is clamped round it. The inner electrode has a 4 mm hole for connection. Capacitance: approx. 2,000 pF; 26 cm high, dia. 100 mm (2 litres).

538 82
High-tension capacitor, capacitance 5,000 pF (5×10^{-9} F), operating voltage: 3,000 V, maximum voltage 5,000 V. Suitable as source of voltage for electrostatics experiments.

When charged with the Van de Graaff generator or Wimshurst machine, the capacitor will supply a constant voltage for some considerable time. A spark gap that will spark over at 5,000 V is provided as a protection for the capacitor.

In case, 11.5×8.5×3 cm^3 in size, with two screw terminals with 4 mm sockets for connection.

540 09
Electroscope, for indicating D.C. and A.C. voltages up to approx. 8 kV. The apparatus is similar to Braun's electrometer in construction and is clearly seen to consist of two essential parts: one pointer with holder, to which voltage is supplied, and one earthed ring insulated from it. This arrangement facilitates understanding the mode of action; moreover, it makes for a defined distribution of the electric field and good reproducibility of the readings.

The electroscope may be used for simple measurements. Preferably, shadow projection should be used and a scale should be drawn on the projection screen.

The needle is suspended on points; complete with capacitor plate and saddle base with clamping screw.

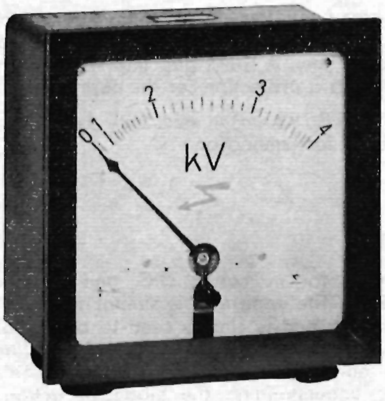
540 37
High-tension voltmeter, according to Braun, for 10 kV. Low-capacitance static instrument for measuring D.C. and A.C. voltages and high-frequency voltages up to 1 Mc/s. Range 0 to 10 kV, with scale divided in 1 kV.

In metal case, dia 21 cm, insulated, with stand base and leveling screws.

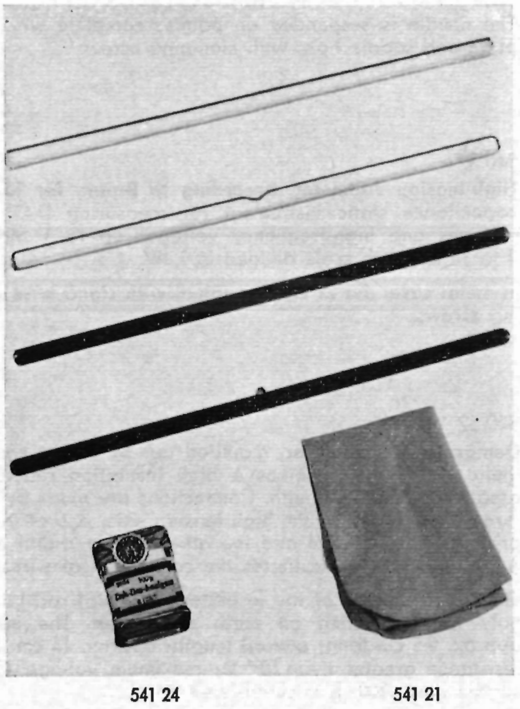
540 52
Demonstration insulator, moulded out of a new type of synthetic resin that combines a high insulation resistance with great mechanical strength. Connections are made by means of three 4 mm holes on the high tension side, one of these being provided in the axial and the other two in radial directions. A clamping screw facilitates the connection of wires.

On the other side of the insulator the metal rod has a 4 mm hole for connecting an earth connection. The insulator is approx. 5.5 cm long; overall length: approx. 14 cm, insulation resistance greater than 10^{14} Ω; maximum voltage 15 kV. The saddle base (300 11) is suitable as base.

540 38



540 39



541 01

541 02

541 04

541 05

541 24 541 21

540 38
Electrostatic voltmeter for 1 kV, for static voltage determinations, which are important even in the introductory treatment of electricity and permit a convenient and exact performance of electrostatic measurements; the instrument is even useful in electronic circuits (e.g. checking Geiger-Müller tube voltages). The instrument works according to a capacitor principle, is well damped, and readings are convenient to take with a pointer and scale. The new, high-grade synthetic insulators are largely insensitive to atmospheric humidity. The time constant of the capacitative system is of the order of several hours.

Range:	0 to 1 kV, with scale divided in units of 20 V, starting at 200 V;
Accuracy:	1.5% of full scale deflection;
Capacitance:	approx. 25 pF;
Insulation resistance:	approx. 10^{14} Ω;
Casing:	18×18×18 cm^3, with highly insulated 4 mm connecting socket on the rear, and earthing socket.

540 39
Electrostatic voltmeter for 4 kV; design and use same as for 540 38, but with a different voltage range. The instrument is very suitable for checking the voltage in experiments with the Wulf electroscope (see p. 132). The time constant of the capacitive system is greater than 30 min.

Range:	0 to 4 kV, with 100 V scale divisions, starting at 1 kV;
Accuracy:	1.5% of full scale deflection;
Capacitance:	approx. 10 pF;
Insulation resistance:	approx. 10^{14} Ω;
Casing:	18×18×18 cm^3, with highly insulated 4 mm connecting socket on the rear, and earthing socket.

541 01
Glass tube, for charging by friction, approx. 25 cm long. For rapid charging we recommend using leather (541 21) treated with amalgam (541 24).

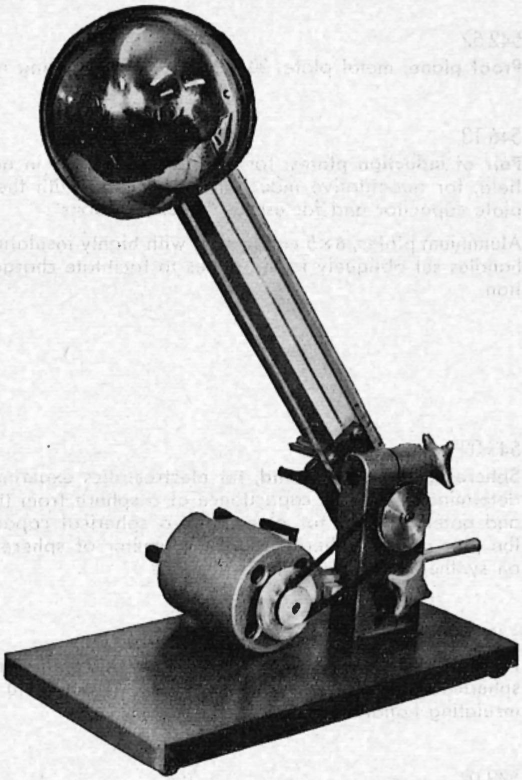
541 02
Glass tube with bearing pan, for demonstrating the forces of attraction and repulsion between electric charges. When supported on a point, the tube will rotate practically without friction, even under the influence of very small forces; approx. 25 cm long. For charging we recommend: leather (541 21) and amalgam (541 24) and as support with point we recommend the stand for the magnetic needle (513 51).

541 04
Plastic rod, for charging by friction, made of specially selected, highly insulating material that can be charged by rubbing with wool, silk, and other textile fibres; approx. 25 cm long.

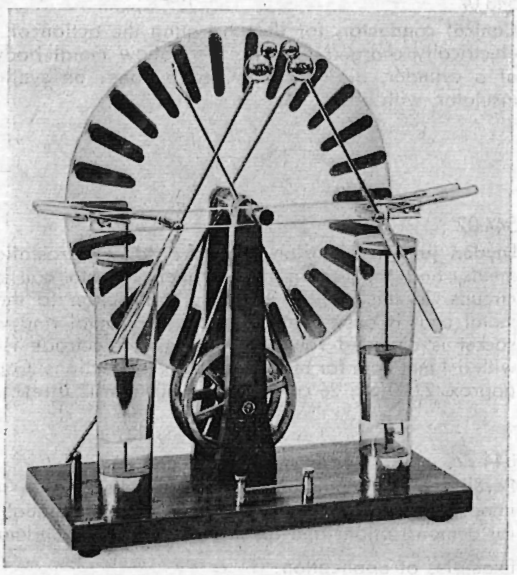
541 05
Plastic rod with bearing pan, made of the same material as 541 04. The rod can be used to demonstrate the forces of attraction and repulsion between electric charges. When supported on a point, it will rotate practically without friction, even under the influence of very small forces; approx. 25 cm long. As support with point, we recommend the stand for the magnetic needle (513 51).

541 21
Leather, for electrostatic charging of glass rods by rubbing. The efficiency is improved by previously treating the leather with amalgam (541 24).

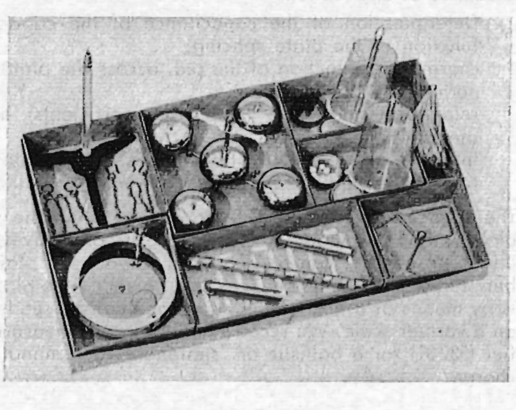
541 24
Amalgam, 100 g; composed as indicated by Kienmayer (Journal de Physique XXXIII, p. 96); for impregnating leather that is to be used for electrostatic charging of glass rods by rubbing.



541 70
with
563 35



541 65



541 68

541 70

Van de Graaff generator, electrostatic machine for producing charges that has been found very convenient in teaching. Clear design, will work even under adverse conditions. The machine can be used for introductory experiments in electricity, as source of high tension for experiments with the Wulf electroscope and, within limits, for operating discharge tubes. A specially interesting application is the operation of the field emission electron microscope.

The generator is supplied with a hand crank, but this suffices only for producing small powers. We therefore recommend using the driving motor (563 35 or 563 36); a clamping device for mounting the stand rod of the motor – which is inserted horizontally – and a belt pulley for the V-belt drive are provided on the generator. When the generator is motor-driven, all its potentialities can be fully exploited.

The insulator can be tilted about the driving axle. By tilting it the position at which the maximum voltage is obtained can be found. The belt runs over three guide rollers and one friction roller for producing the charge, with friction brush and three knife-edges.

Technical data:

Diameter of sphere: 18 cm; sphere can be taken off,
Width of endless belt: 5 cm,
Length of insulator: 43.5 cm,
Short-circuit current: 20 μA,
max. voltage: 240 kV.

On base plate, 40×24 cm^2, with rubber feet for better stability; without motor.

563 35

Driving electric motor for 220 V, 70 W, for driving the generator models with constant speed as required for measurements. Also suitable for many other purposes, especially for driving the Van de Graaff generator.

Power output up to 45 W; max. speed 6,000 r.p.m., with 2 belt pulleys, dia. 35 and 60 mm, respectively, V-belt and bench clamp.

The speed of revolution can be regulated by means of a 320 Ω rheostat (537 23) connected in series.

563 36

Driving electric motor for 110 V, 70 W, otherwise same as for 563 35. The speed of revolution can be regulated by means of a 110 Ω rheostat (537 24).

541 65

Wimshurst machine, with plastic plates, dia. 31 cm, max. spark length approx. 120 mm.

Wimshurst's classical design for the safe production and demonstration of high D.C. voltages. The plates are now made of transparent plastic, and no longer of hard rubber as in the original design, and have thereby been rendered particularly durable.

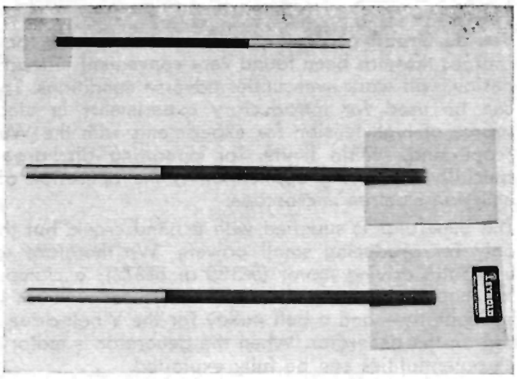
On base board, 29×36 cm^2 in size, with two Leyden jars, V-belt drive and spark gap.

541 68

Set of accessories for electrostatics experiments, for use with the Van de Graaff generator (541 70) or the Wimshurst machine (541 65). The set is very suitable for demonstrating some important phenomena of electrostatics in an entertaining and memorable manner. It contains the following parts:

1 paper brush,
1 electric whirl,
1 set of electric chimes,
1 luminous pane,
1 dancing pith ball apparatus,
1 air cleaning apparatus (smoke dispeller),
1 running glass ball apparatus

Complete with stand with insulating rod for mounting these parts, two chains for connection and two metal handles for electric shocks.



542 52

546 13

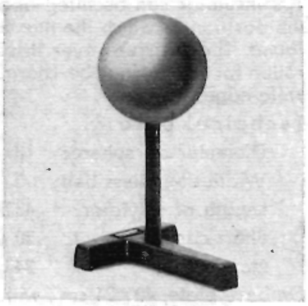
542 52

Proof plane, metal plate, 30×30 mm², on insulating rod.

546 13

Pair of induction plates, for separating charges in an electric field, for quantitative induction experiments with the parallel plate capacitor and for use as "electric spoons".

Aluminium plates, 6×5 cm² in size, with highly insulating plastic handles set obliquely to the plates to facilitate charge separation.



543 02

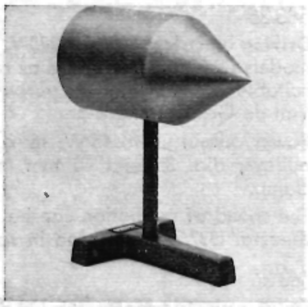
543 02

Sphere on insulating stand, for electrostatics experiments, e.g. determination of the capacitance of a sphere from the charge and potential, and for assembling a spherical capacitor with the pair of hemispheres (543 05). Diameter of sphere 100 mm; on synthetic resin insulator with base.

543 05

543 05

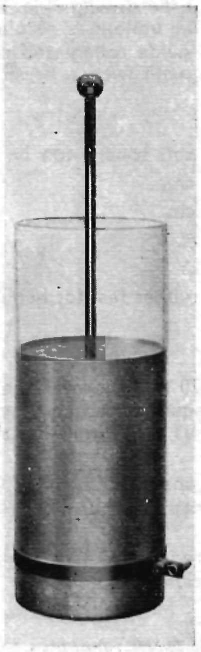
Pair of hemispheres according to Cavendish, for making a spherical capacitor with the sphere (543 02); dia. 110 mm, with insulating handles.



543 07

543 07

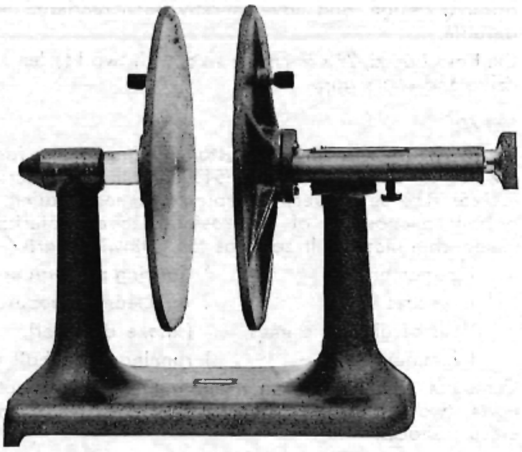
Conical conductor, for demonstrating the action of points on electrically charged objects. The hollow metal body consists of a cylinder, dia. 100 mm, and a cone; on synthetic resin insulator, with base.



544 02

544 02

Leyden jar; high-tension capacitor for electrostatics experiments, and for use in high-frequency Tesla coil oscillatory circuits. In this design, electrical connection to the external metal coat is easy to make because a metal ring with 4 mm socket is clamped round it. The inner electrode is provided with a 4 mm hole for making electric connections. Capacitance: approx. 2,000 pF; 26 cm high, dia. 100 mm (2 litres).



544 22

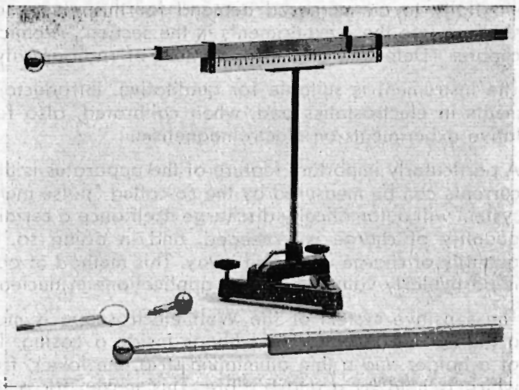
544 22

Parallel plate capacitor; measuring device for a number of important electrostatics experiments, which is equally suitable for demonstrations and for practical work by students:

Examples of application:

- Determination of the capacitance of the capacitor as a function of the plate spacing;
- charge as a function of the p.d. across the plates;
- permittivity of free space ε_0;
- relative permittivities (dielectric coefficients) of various dielectrics;
- intensity of the electric field between the plates and the forces exerted by it on charged objects; and others.

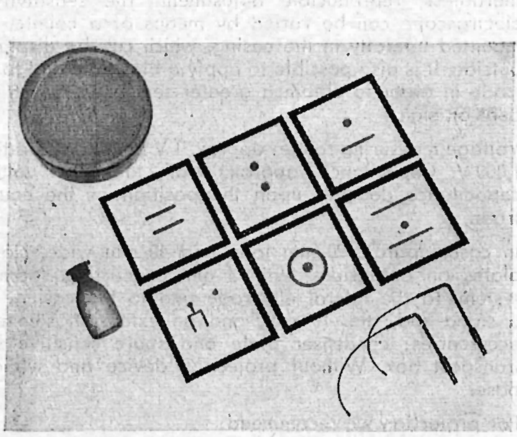
The capacitor plates are 260 mm in diameter. The stationary plate is highly insulated, the other one is conductively connected to the base. It can be displaced to vary the plate spacing between 0 and 70 mm. The fine adjustment of the plate spacing is by means of a micrometer screw and can be read to 1/10 mm on a vernier scale. We recommend using our measuring amplifier (532 01) for a ballistic or "stationary" determination of the charge.



516 20

516 20

Accessories for demonstrating Coulomb's law and the forces acting in electric fields, for measurements with the torsion balance (516 01). The equipment can be used to measure the forces between electrically charged spheres as a function of the charges on them and their distance from one another, and to determine the permittivity of free space. Moreover, it can be used to measure the force exerted on an electric charge in the homogeneous electric field of the parallel plate capacitor. For further details see p. 112.



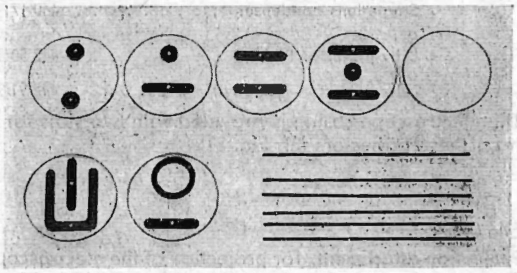
545 12

545 12

Apparatus for demonstrating the lines of force of an electric field, suitable for vertical projection. Set of 6 glass plates with glued-on metal plates in various arrangements, suitable for producing electric fields with characteristic configurations of the lines of force which are rendered visible by means of plastic fibres. Flexible conductors for supplying high tension are included with the set.

Glass plates, 9×9 cm² in size, the demonstration of which in vertical projection is most impressive. We recommend using the arrangement of Fig. 43, p. 78, with the projection frame (441 51). As source of H.T. we recommend using the high-tension power supply (522 37) or the demonstration transformer, assembled from parts 562 11, 562 12, 562 14 and 462 17; or the Van de Graaff generator (541 70).

Complete with plastic fibres and sifter-top jar.



442 63

442 63

Set of glass plates with electrodes, similar to 545 12, but with 6 round glass plates of 50 mm dia. fitting the base plate with connecting sockets (442 61) and suitable for projection with the Leitz projectors PRADO or "pradovit".

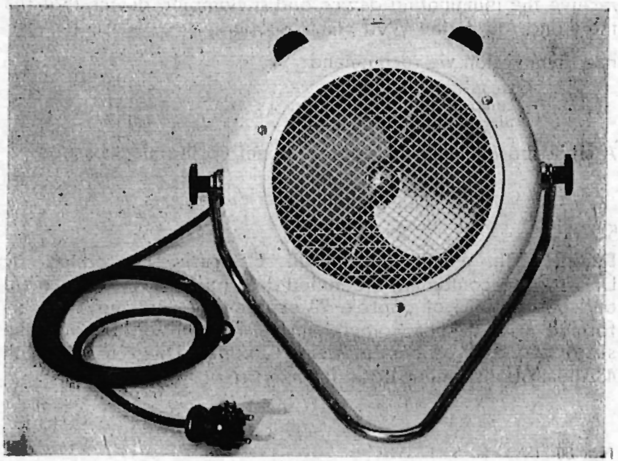
For a detailed description see the chapter "Projection Experiments" in the section "Optics", pp. 101–105.

514 79 (not shown)

Sifter-top jar for plastic fibres, made of plastic, capacity 20 cm³, without plastic fibres.

545 13 (not shown)

Plastic fibres, for rendering the lines of force of electric fields visible, especially suitable for projection. The fibres are approx. 1 mm long; approx. 45 g.



545 20

545 20

Fan, for use as cool or warm air blower, 220 V. The insulation resistance of the insulators used in electrostatics experiments can be improved considerably if the components are dried with hot air shortly before or during the experiment. The procedure is recommended especially in conditions of high humidity, e.g. in crammed lecture halls, as the superficial water films on insulators will thereby be removed.

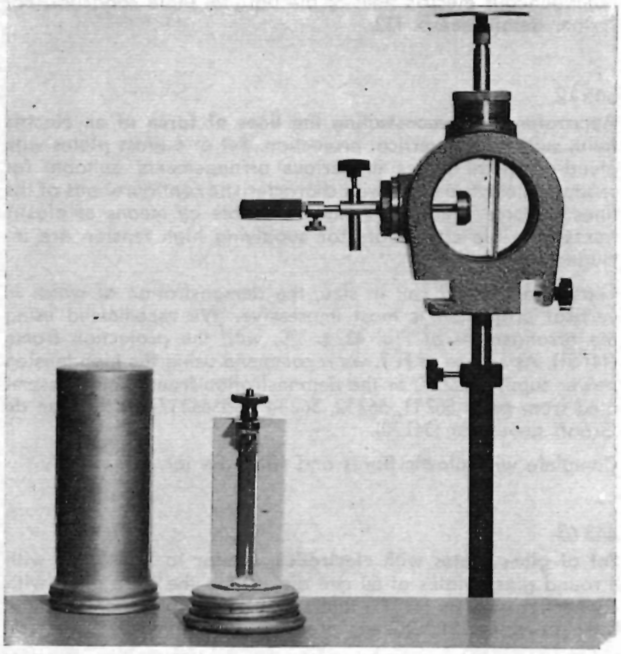
The fan is contained in a metal casing on a metal base, swivelling, with three speeds and 3 degrees of heating, of 750, 1,250, and 2,000 W, respectively, and one position for cold air. Overheating protection and indicator lamp are provided. Complete with mains cable.

545 21 (not shown)

Fan, for use as cool or warm air blower, 110 V, made of plastic, on metal base with variable inclination, with two speeds and two degrees of heating, of 700 and 1,000 W respectively, and one position for blowing cold air, and one fuse. Complete with mains cable.

546 00

Wulf electroscope, for projection. This instrument was first used in education in 1925 and has been greatly appreciated ever since on account of its eminent suitability for teaching purposes. During the last few years it has been above all its use for introductory experiments in radioactivity, which Wulf had already suggested many years ago, that contributed substantially to an increased demand for this electroscope. We shall go into these experiments in the section "Atomic Physics", chapter "Detection and measurement of radioactivity".



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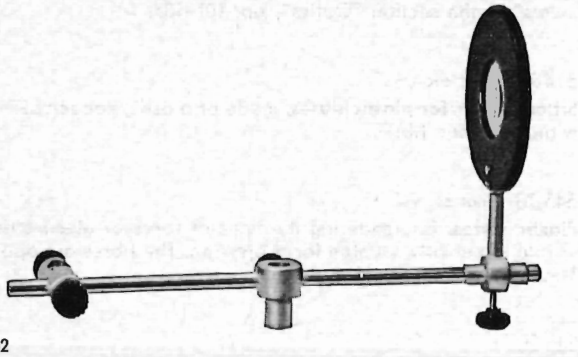


546 02

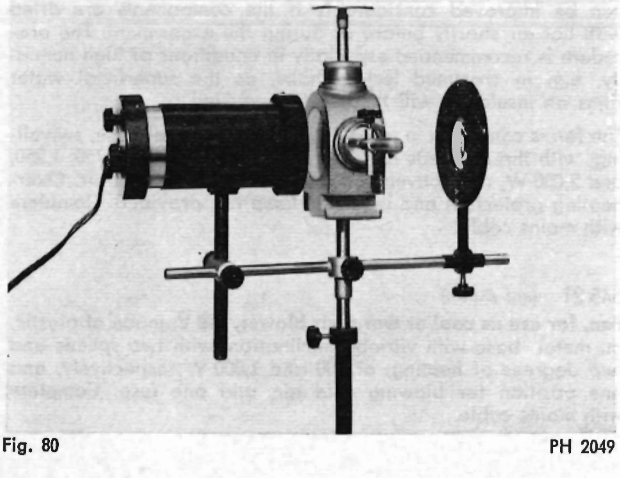


Fig. 80 PH 2049

The instrument is suitable for qualitative, introductory experiments in electrostatics and, when calibrated, also for quantitative experiments on electromagnetism.

A particularly important feature of the apparatus is that minute currents can be measured by the so-called "pulse method": the system will automatically discharge itself once a certain limiting quantity of charge is exceeded, and in doing so, a certain quantity of charge is carried away. This method of observation is particularly valuable for the applications in nuclear physics.

The sensitive system of the Wulf electroscope is mounted on a high-grade insulator and hangs inside a casing. It consists of a holder and a thin aluminium strip, the lower, free end of which is held by a quartz fibre. This makes for a practically inertialess, reproducible adjustment. The sensitivity of the electroscope can be varied by means of a counter-electrode mounted laterally in the casing, which can be displaced from outside. It is also possible to apply a bias potential to this electrode in order to obtain a greater sensitivity, which is dependent on sign.

Voltage measuring range: approx. 1 V (with bias) up to approx. 1,000 V. Capacitance: approx. 5 pF; the exact value of the capacitance depends upon the position of the counter-electrode.

In case, approx. 90 mm long and 40 mm wide, closed glass plates on both sides; with 4 mm connecting sockets to the system, to the lateral electrode and to the casing, and with a stand rod, dia. 10 mm, and an extension sleeve. Further accessories: condenser plate and spare sensitive system in transport box. Without projection device and without stand base.

For projection we recommend:

Projection attachment	546 02
Lamp-house	450 60
Lamp, 6 V, 30 W	450 51
Single-lens condenser	460 17
or:	
Leitz-projector PRADO	442 50/51
or:	
Leitz-projector "pradovit"	442 91/93

The electroscope casing is provided with two slots for mounting it on these projectors (cf. Fig. 81).

546 02

Projection attachment, for projection of the electroscope system. Consists of one rod, approx. 25 cm long, with projection lens, f = 100 mm, that can be displaced along the rod, a holder to receive the illuminating device and a clamping device that fits the stand rod of the Wulf electroscope.

For illumination we recommend:

Lamp house	450 60
Lamp, 6 V, 30 W	450 51
Single-lens condenser	460 17

A stand base (300 02) is required to set up the electroscope.

546 462

Booklet: Th. Wulf, "The Wulf Electroscope"; edited by Dr. Kröncke, containing a detailed description of the instrument and descriptions of approx. 90 experiments that may be performed with it. For comprehensive information beyond the scope of the Directions for Use. 110 pages, DIN A 5 size; with 43 illustrations, paper back. In English.

Fig. 80
Wulf electroscope with projection attachment and illuminating device.

Ancillary equipment for electrostatics experiments

The following is a list of the items that can be used to do experiments in electrostatics.

Other parts that may be used for experiments in radioactivity are listed in the section "Atomic Physics", chapter "Detection and measurement of radioactivity".

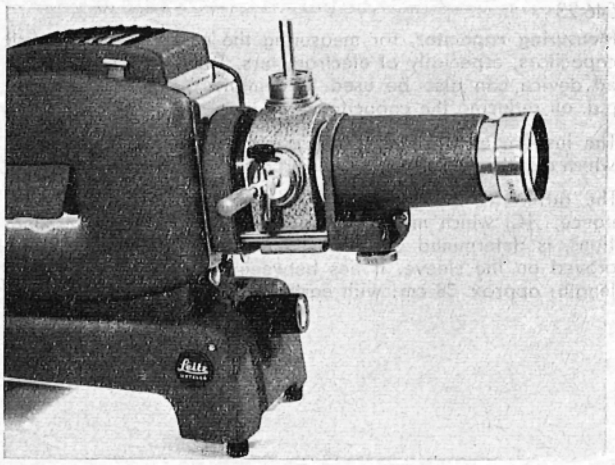
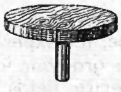


Fig. 81 PH 2050

Fig. 81
Wulf electroscope fitted on Leitz-Projector PRADO for projection.

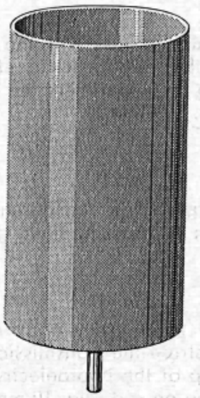
546 11

Wooden stage, to be fitted on the Wulf electroscope for demonstrating the separation of charges by friction; wooden disc, dia. 48 mm, on 4 mm plug.


546 11

546 12

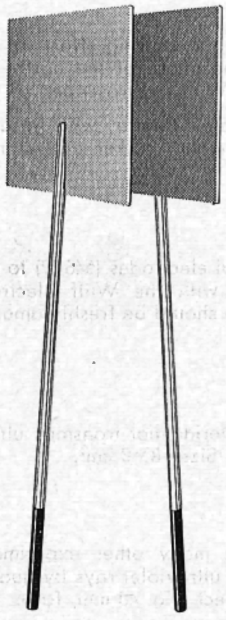
Faraday's ice pail, for studying the charge distribution on a hollow metal container. This pail may be fitted on the Wulf electroscope, or on the electroscope (540 09), or can be used with the electrostatic voltmeter, 1 kV (540 38). In all these cases it can be shown that the interior of the pail remains uncharged when the pail is charged up; height 13 cm, dia. 7.5 cm, on 4 mm plug.


546 12

546 13

Pair of probe plates, suitable for demonstrating the separation of charges in the electric field, for quantitative induction experiments with the parallel plate capacitor, and as "spoon" for transferring charges.

Aluminium plates, 60×50 mm², with highly insulating plastic handles, which are attached at an angle to facilitate the separation of charges.


546 13

546 14

Capacitor plate, for demonstrating the relation between capacitance and p.d. in a capacitor; consists of a metal plate, dia. 45 mm, with earthing socket and insulating rod, and a styroflex plastic foil, 60×70 mm², approx. 0.05 mm thick.

546 14

536 22

Resistor, 100 MΩ. The use of this resistor is recommendable whenever the Wulf electroscope is to be used in conjunction with powerful sources of voltage in order to limit the current in the case of inadvertent short-circuits and prevent destruction of the system.

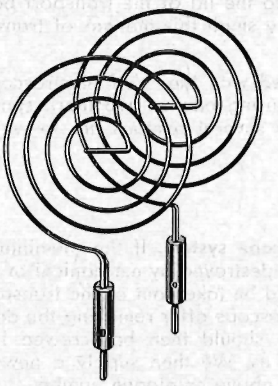
The resistor is very simple to use because it is contained in a capsule with connecting plug and socket. It can also be used for many other experiments.

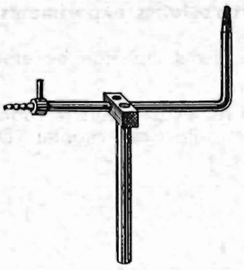
536 22

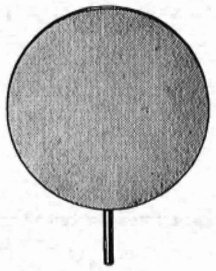
546 29

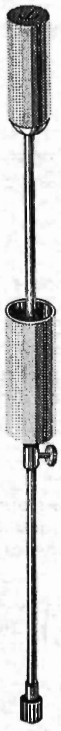
Pair of spiral electrodes; electrodes which pass light, to demonstrate the conductivity of ionised regions of air and for a particularly impressive demonstration of the photoelectric effect (see section "Atomic physics", p. 176).

Made of bent brass wire, dia. approx. 90 mm, with 4 mm plug and 4 mm socket.


546 29


546 30


546 31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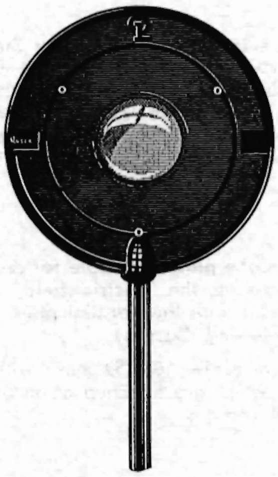
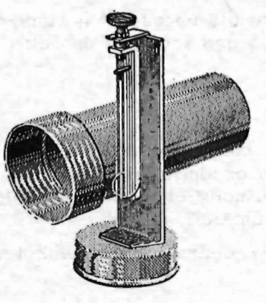

469 07

546 32


546 50

546 23

Measuring capacitor, for measuring the capacitance of small capacitors, especially of electrometers. The excellently insulated device can also be used to demonstrate the increase of p.d. on reducing the capacitance.

The instrument is a cylindrical capacitor, the capacitance of which may be varied by displacing an external, earthed sleeve.

The difference between the maximum and minimum capacitance, ΔC, which must be known for capicitance determinations, is determined very exactly before delivery and is engraved on the sleeve. It lies between 20 and 30 pF. Overall length: approx. 38 cm; with earthing socket.

546 30

Flame probe, for experiments on the ionising effects of flames, the voltage gradient in the atmosphere of the earth, and to map out electric fields with the Wulf electroscope.

Small gas burner mounted on an insulator, with hose nipple for connecting to gas tubing, 4 mm socket and stand rod, without gas tubing.

546 31

Zinc plate, for use with the spiral electrodes (546 29) to demonstrate the photoelectric effect with the Wulf electroscope. Prior to the experiment the plate should be freshly amalgamated; dia. 100 mm.

546 32

Plastic plate, of transparent material that transmits ultraviolet light, in contrast to silica glass. Size: 8×8 cm².

469 07

Quartz lens, used, apart from many other experiments, to demonstrate the transmission of ultraviolet rays by quartz with the help of the photoelectric effect, dia. 40 mm, focus 150 mm, in frame on rod, dia. 10 mm.

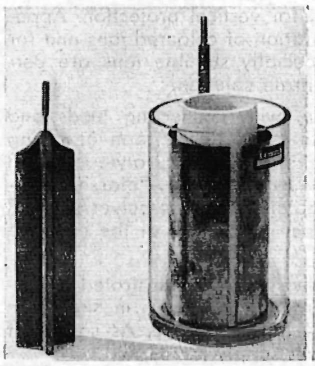
546 50

Spare sensitive system in transport box, complete system as used in the Wulf electroscope, with holder, aluminium strip and quartz fibre, screwed to the lid of the transport box. The mass of the strip being very small this manner of transport is completely safe.

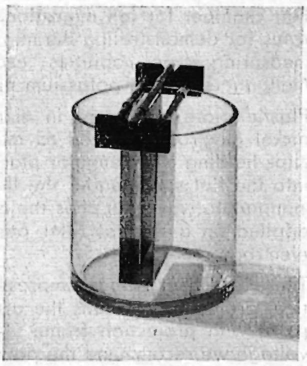
One such system is supplied with the Wulf electroscope; we recommend, however, procuring one or two more spare sensitive systems, especially if several persons are to work with the same instrument.

546 51

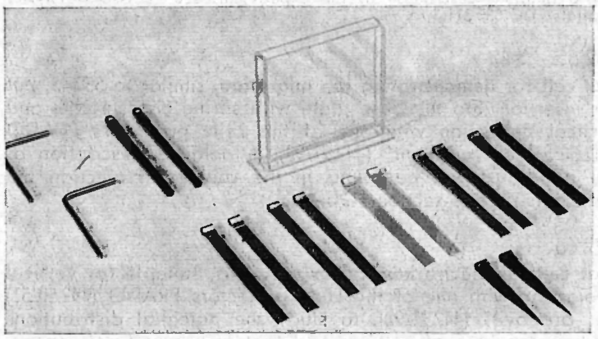
Repairing a Wulf electroscope system. If the aluminium strip of the Wulf electroscope is destroyed by mechanical or electric causes, a new system should be taken out of the transport box and inserted into the electroscope after removing the damaged one. The damaged system should then be screwed into the transport box and sent to us. We then supply a new system in transport box under the above catalogue number.



522 12



552 13



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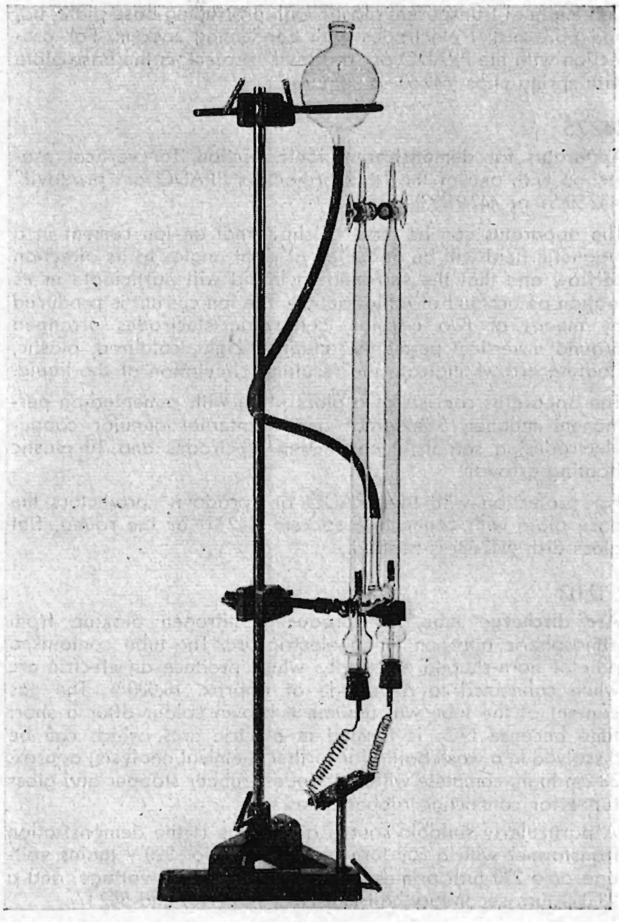


552 33

522 12

Daniell cell. Very clear embodiment of a primary cell, consisting of a zinc cross, a copper cylinder and a porous earthenware cylinder. The two metal electrodes are provided with 4 mm sockets; complete with glass cylinder, dia. approx. 11 cm, 16 cm high; without electrolyte.

552 13

Copper voltameter, for measuring the increase or decrease in the mass of copper electrodes when current flows through the electrolyte.

The apparatus consists of one plate-shaped and one U-shaped electrode, both approx. 8×10 cm^2 in size, for suspension in a glass vessel, with 4 mm sockets for connection; complete with glass vessel, dia. 12 cm.

552 14

Electrolytic cell, for studying the conduction of current in liquids using various electrodes and electrolytes. Suitable both for direct observation, and for demonstration in projection.

Consists of: 1 Plate glass box, 100×100×10 mm^3,
1 Pair of electrode holders,
1 Pair of electrodes of each of the following: copper, carbon, nickel, aluminium, lead, zinc; without electrolytes.

552 33

Hofmann's voltameter for the electrolysis of water; H-shaped glass vessel with etched-in graduation for quantitative determination of the quantities of gaseous matter formed in electrolysis. The volumes of both gases can be read at atmospheric pressure, without additional hydrostatic pressure, as the pressure equalisation vessel is connected by means of a rubber tube and its height can be varied.

The apparatus consists of: Glass vessel, approx. 48 cm high, with stopcocks, pressure equalisation vessel with rubber tube, pair of platinum electrodes with rubber stoppers, terminal block for current supply and stand equipment (stand base, stand rod, 75 cm long, 2 Leybold bosses, 1 Bunsen clamp, 1 ring with stem).

552 31

Hofmann's voltameter for the electrolysis of water, complete as described under 552 33, but without stand equipment.

552 22

Pair of platinum electrodes, rectangular plates made of platinum foil, 20×10 mm^2 in size, with current supply wires sealed in glass; complete with rubber stopper fitting Hofmann's voltameter.

1 Pair of platinum electrodes is supplied with Cat. Nos. 552 33 and 552 31.

552 21 (not shown)

Pair of nickel electrodes, for electrolysis in alkaline solutions, approx. 55×8 mm^2 in size, complete with rubber stoppers.

552 34 (not shown)

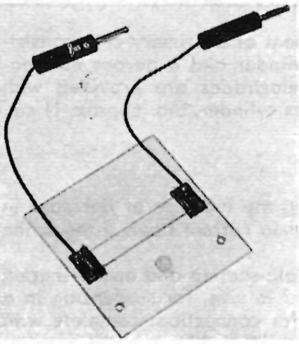
Pair of carbon electrodes, made of compressed carbon, approx. 20 cm long, for simpler, qualitative work, for example when metal separates from the solution and would foul a platinum electrode; complete with rubber stoppers.

552 38

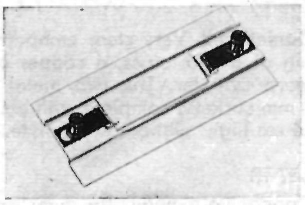
Spare glass vessel with graduation, for Hofmann's voltameter, Cat. Nos. 552 33 and 552 31.

552 29

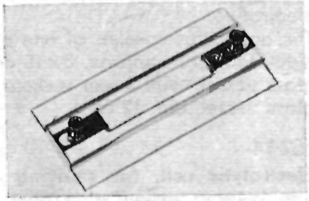
Terminal block for electrodes, for connecting the electrodes to the source of current. Insulator block with extendable wires, screw terminals with 4 mm sockets, and stand rod, dia. 10 mm; supplied with 552 33 and 552 31.



552 43



442 65



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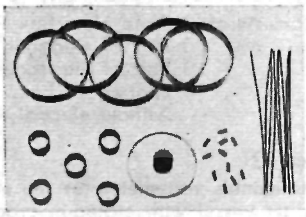

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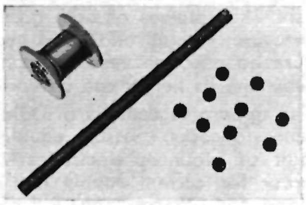

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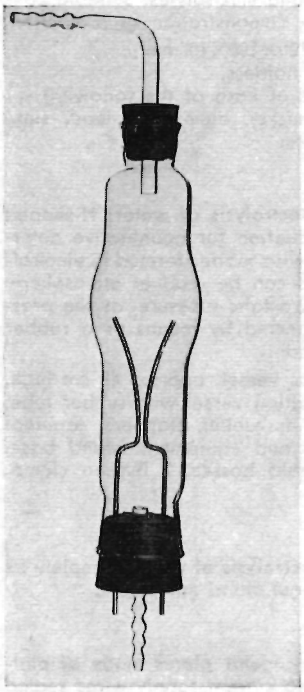

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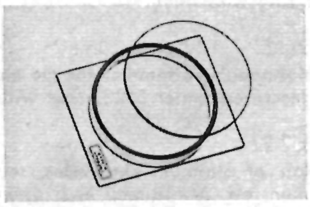


442 68

552 47

Graphite rod and nickel wire. Graphite and pure nickel are particularly suitable for measuring the potential distribution in conducting and non-conducting liquids. Such measurements can easily be shown in vertical projection using the round glass dish (442 68) and the base plate with spring clips and connecting sockets (442 61). As high-resistance measuring instrument we recommend the measuring amplifier (532 01).
This set consists of the following parts:

1 Graphite rod, approx. 20 cm long, dia. approx. 10 mm
10 Graphite discs
1 Reel of pure nickel wire, approx. 2 m long, dia. 1 mm.

For projection we recommend using one of the Leitz projectors PRADO or "pradovit", or the projection arrangement shown in Fig. 36, p. 72.

473 32

Nitrobenzene, chemically pure, for electrical experiments; 100 g.

442 68

Flat glass dish, round, for demonstrating in projection experiments in liquids, such as ionic friction, electric lines of force in oil, tracing equipotential lines, etc.
Round dish made of plate glass, dia. 50 mm, with protruding rectangular base plate and lid.

552 43

Flat chamber for ion migration, for vertical projection. Apparatus for demonstrating the migration of coloured ions and for measuring ionic mobilities; especially suitable ions are permanganate ions in potassium nitrate solution.

Plastic plate, 9×9 cm^2 in size, with connecting leads and nickel electrodes spaced 65 mm apart in the form of spring clips holding a rectangular plastic lid. The electrolyte is drawn into the flat space under the lid by capillarity. Potassium permanganate which supplies the coloured ions is pulverised and applied on a strip of filter paper introduced at the negative electrode.

The experiment is most impressive when demonstrated in vertical projection. For this the arrangement shown in Fig. 43 on p. 78 with projection frame (441 51) is suitable. As source of voltage we recommend the power supply (522 33/35).

For a detailed description of the experiment, see "LEYBOLD Physics Leaflets" DC 537.311.3; a.

442 65

Flat cell for demonstrating ion migration, similar to 552 43, but for insertion into the base plate with spring clips (442 60) and vertical projection with one of the Leitz projectors PRADO (442 50/51) or "pradovit" (442 91/93). A detailed description of the apparatus will be found in the chapter "Projection Experiments" in the section "Optics".

442 66

Flat cell for electrochemical experiments, suitable for vertical projection with one of the Leitz projectors PRADO (442 50/51) or "pradovit" (442 91/93), to study the potential distributions both in the case of uniform and that of non-uniform concentration of the electrolyte, for measuring conductivities, etc.

Cell made of transparent plastic with protruding base plate, lid, and pure nickel electrodes with connecting sockets. For projection with the PRADO or "pradovit" projectors the base plate with spring clips (442 60) is required.

442 75

Apparatus for demonstrating ionic friction, for vertical projection with one of the Leitz projectors PRADO or "pradovit" (442 50/51 or 442 91/93).

The apparatus can be used to show that an ion current in a magnetic field will be deflected at right angles to its direction of flow and that the surrounding liquid will participate in its motion on account of ionic friction. The ion current is produced by means of two circular, concentric electrodes arranged around a vertical permanent magnet. Light, coloured, plastic, floating arrows indicate the resulting circulation of the liquid.

The apparatus consists of a glass plate with cemented-on permanent magnet, 5 external and 5 internal annular copper electrodes, a set of 10 connecting electrodes and 10 plastic floating arrows.

For projection with the PRADO or "pradovit" projectors the base plate with connecting sockets (442 61) or the round, flat glass dish (442 68) is needed.

552 03

Arc discharge tube, for producing nitrogen dioxide from atmospheric nitrogen in an electric arc. The tube contains a pair of horn-shaped electrodes which produce an electric arc when connected to a voltage of approx. 10,000 V. The gas content of the tube will assume a brown colour after a short time because NO_2 is formed in electric arcs, which can be dissolved in a wash bottle for further chemical analysis; approx. 38 cm high, complete with electrodes, rubber stopper and glass tubes for connecting rubber tubes.

A particularly suitable source of voltage is the demonstration transformer with a 500 turn primary coil for 220 V mains voltage or a 250 turn primary coil for 110 V mains voltage, and a 23,000 turn secondary coil (562 11/12/14 or 13, and 562 17).

GAS DISCHARGE

Electric discharges in gases and the luminous phenomena by which they are accompanied have contributed in an important manner towards our knowledge of atomic physics. That is why they are an important starting point for the experimental treatment of atomic physics in education. For demonstrating these experiments sealed tubes adjusted to a certain pressure were almost exclusively used in former times. Such tubes have, however, the disadvantage that the pressure to which they are adjusted decreases in time owing to adsorption of gas, so that increasingly higher voltages are required for their operation, ultimately resulting in the occurrence of X-rays with appreciable intensities.

Realising the radiological hazards that may be involved by such effects, we have reduced the manufacture of such sealed tubes. Instead, we recommend using only open tubes which are freshly evacuated down to their operating pressure during each experiment, using a vacuum pump. These, therefore, can always be operated at the same, low, operating voltages. If, therefore, one ensures that the source of voltage only supplies the (comparatively low) voltage needed for operation, then the X-rays issuing from such tubes remain below the background radiation level.

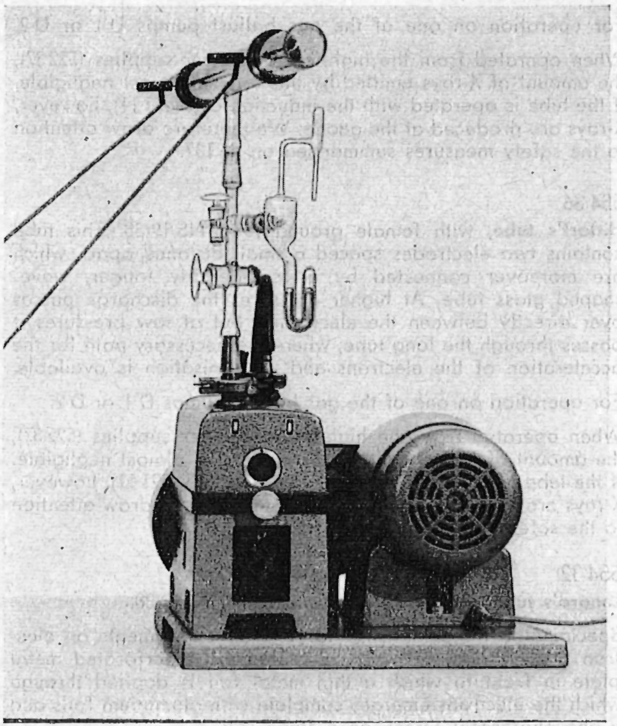


Fig. 82 PH 2051

Gas discharge in high vacuum to demonstrate cathode and canal rays.

Discharge tube (554 16) on glass adaptor (554 00) with vacuoscope C (160 23) attached, mounted on the intake port of a gas ballast pump D 2 (110 12 S/13 S). As source of high tension we recommend two high-tension power supplies (522 37).

In order to satisfy these conditions we recommend using two high-tension power supplies (522 37) in series, which will suffice to operate all the gas discharge tubes listed here, apart from the Lenard tube and the special X-ray tubes. Many experiments can even be performed with one such power supply; a second unit is, however, of great advantage in the cathode ray region.

Our quarterly House-Magazine, "Die LEYBOLD-Welle", No. 15/16, contains a report about investigations on the subject.

The induction coil (521 11) can also be used as a source of high tension; but the voltage peaks that occur produce a noticeable X-radiation in most tubes. We have measured this radiation in the case of the tubes supplied by us and have published the results in the booklet "Dosimetrie und Strahlenschutz im Unterricht" (in German only). This booklet contains many valuable pieces of information and will be sent to customers on request.

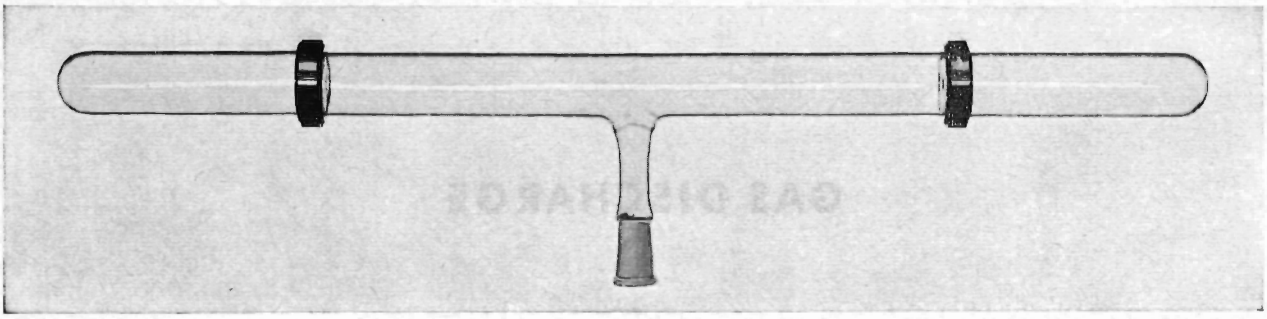
When using the induction coil, the following points should be noted:

1. All cathode ray tubes should only be switched on briefly. The phenomena should be explained previously or afterwards.
2. Pupils should not step close to an operating tube, but keep at a distance of at least 3 m from it. A thick plate-glass plate will reduce the dose-rate to about ⅓ and is, therefore, useful as an observation window.
3. The lecturer should likewise not step close up to the tube and should check the dose received by himself by means of a pocket dosimeter (546 60).

The open tubes can be evacuated with two-stage rotary vacuum pumps which should be provided with glass or metal adaptors for shutting off when attaining the operating pressure, for admitting air to the tubes and for the connection of vacuum gauges. An introductory paragraph and details on the assembly of vacuum arrangements will be found in the section "Vacuum", p. 44 et seq.

We recommend the following vacuum pumps and ancillary equipment:

Two-stage gas ballast pump D 1, with A.C. motor for 220 V, 50 c/s	110 00 S
or	
Two-stage gas ballast pump D 2, with A.C. motor for 220 V, 50 c/s	110 12 S
or	
Two-stage gas ballast pump D 2, with three-phase current motor for 220/380 V, 50 c/s	110 13 S
Glass adaptor, for mounting tube on pump	554 00
or	
Metal adaptor, for mounting tube on pump	378 00
Vacuoscope C	160 23

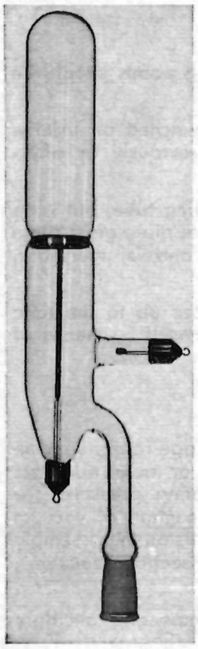


554 16

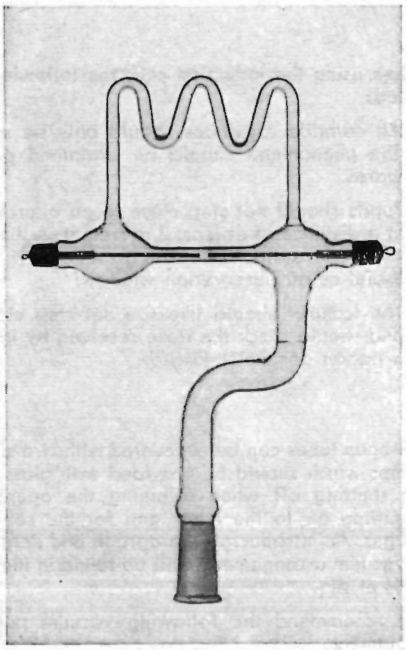
554 16

Discharge tube for evacuation. This tube is suitable for observing all luminous phenomena associated with electric discharges in the various pressure ranges. When evacuating, the characteristic luminous phenomena and dark spaces of a self-maintaining discharge between the electrodes will initially be observed. When the pressure has decreased sufficiently, the charge carriers will pass through the holes in the electrodes and their properties can be studied separately. In this manner the cathode rays and canal rays can be found experimentally.

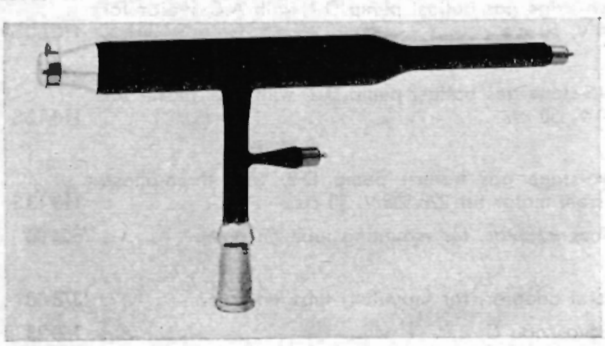
The discharge tube differs in its construction from the simple tubes normally used. It is approx. 70 cm long in all and consists of a cylindrical central part with ground joint NS 19/38 and two end parts. These three glass components are cemented to disc-shaped, bored aluminium electrodes. In this manner a discharge gap of approx. 40 cm length is obtained which is followed by the observation spaces for cathode and canal rays beyond the electrodes. For making the glass-aluminium seals we have used a self-hardening synthetic resin of excellent mechanical and vacuum-technical properties. The electrodes are each provided with a 4 mm hole for making electrical connections.



554 31



554 36



554 32

For operation on one of the gas ballast pumps D 1 or D 2 (110 00 S or 110 12 S/13 S).

When operated from the high-tension power supplies (522 37), the amount of X-rays emitted by this tube is almost negligible. If the tube is operated with the induction coil (521 11), however, X-rays are produced at the anode. We therefore draw attention to the safety measures summarised on p. 137.

554 31

Canal ray tube, with female ground joint NS 19/38. In this tube the cathode is provided with slots which allow the positively charged ions to pass through as so-called canal rays. In the large space beyond the cathode, these rays can be observed very conveniently.

For operation on one of the gas ballast pumps D 1 or D 2.

When operated from the high-tension power supplies (522 37), the amount of X-rays emitted by this tube is almost negligible. If the tube is operated with the induction coil (521 11), however, X-rays are produced at the anode. We therefore draw attention to the safety measures summarised on p. 137.

554 36

Hittorf's tube, with female ground joint NS 19/38. This tube contains two electrodes spaced a small distance apart, which are moreover connected by a considerably longer, wave-shaped glass tube. At higher pressures the discharge passes over directly between the electrodes, but at low pressures it passes through the long tube, where the necessary path for the acceleration of the electrons and the ionisation is available.

For operation on one of the gas ballast pumps D 1 or D 2.

When operated from the high-tension power supplies (522 37), the amount of X-rays emitted by this tube is almost negligible. If the tube is operated with the induction coil (521 11), however, X-rays are produced at the anode. We therefore draw attention to the safety measures summarised on p. 137.

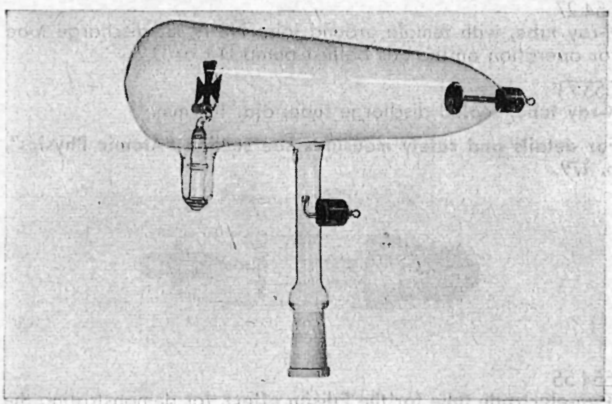
554 32

Lenard's tube, with female ground point NS 19/38.

Special tube for demonstrating Lenard's experiments on electron propagation. The tube is sealed by a perforated metal plate in front to which a thin metal foil is applied through which the electrons emerge; complete with aluminium foils and a phosphorescent screen on a stand rod.

For operation on one of the gas ballast pumps D 1 or D 2.

This tube can only be operated from the induction coil (521 11). It will emit X-rays in operation. We therefore refer to the safety measures summarised on p. 137.



555 55

555 55

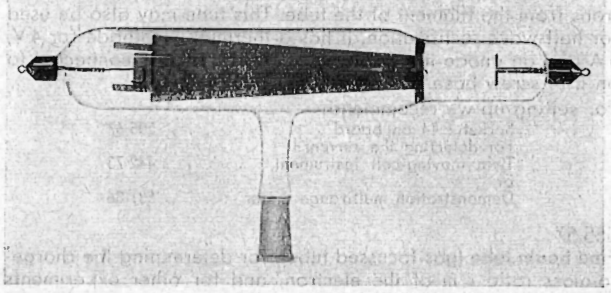
Maltese cross tube, with female ground joint NS 19/38, for demonstrating the fluorescence of glass produced by electrons propagating rectilinearly from the cathode in a self-maintaining gas discharge. A cross in the path of the electrons, whose plane can be rotated till it is parallel or perpendicular to the path of the electrons, will shield these off and appear as a shadow on the fluorescent glass surface.

For operation on one of the gas ballast pumps D 1 or D 2.

When operated from the high-tension power supplies (522 37), the amount of X-rays emitted by this tube is almost negligible. If the tube is operated with the induction coil (521 11), however, X-rays are produced at the anode. We therefore draw attention to the safety measures summarised on p. 137.

555 45 (not shown)

Maltese cross tube, evacuated, on wooden base; otherwise same as for 555 55. This tube can either be operated from the induction coil (521 11) or from a source of high tension yielding more than 10 kV; if the tube is operated from the induction coil, X-rays are formed at the anode. We therefore refer to the safety measures summarised on p. 137.



555 56

555 56

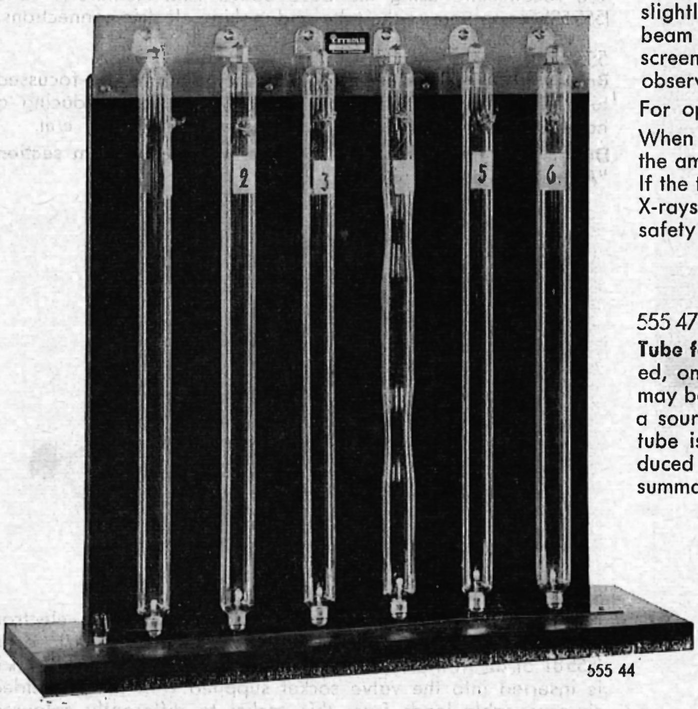
Tube for demonstrating the deflection of cathode rays, with female ground joint NS 19/38. The electrons from a self-maintaining gas discharge emerge as a narrow beam from an anode with a slit. This beam grazes a phosphorous screen slightly inclined to the direction of propagation. The electron beam produces a luminous trace along the whole length of the screen and thus its deflection in a magnetic field is easy to observe.

For operation on one of the gas ballast pumps D 1 or D 2.

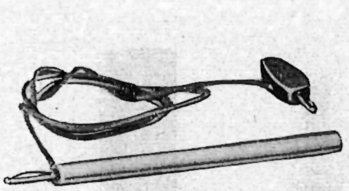
When operated from the high-tension power supplies (522 37), the amount of X-rays ermitted by this tube is almost negligible. If the tube is operated from the induction coil (521 11), however, X-rays will be formed at the anode. We therefore refer to the safety measures summarised on p. 137.

555 47 (not shown)

Tube for demonstrating the deflection of cathode rays, evacuated, on wooden base; otherwise same as for 555 56. This tube may be operated either from the induction coil (521 11), or from a source of high tension yielding more than 10 kV. When the tube is operated from the induction coil, X-rays will be produced at the anode. We therefore refer to the safety measures summarised on p. 137.



555 44

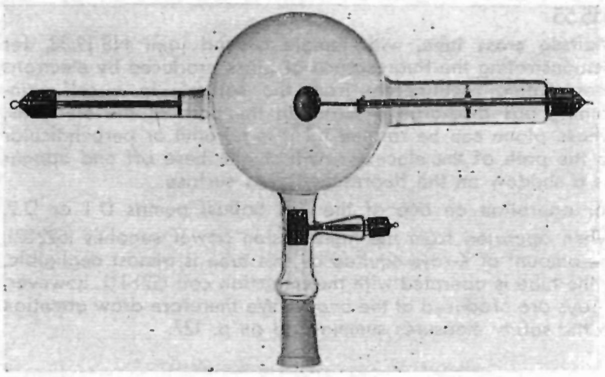


555 44

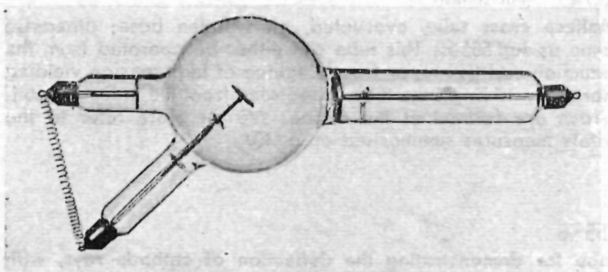
Cross' vacuum scale, consisting of 6 tubes evacuated to pressures of approx. 40; 10; 6; 3; 0.15 and 0.03 Torr. To the individual pressure ranges correspond characteristic discharge phenomena in these tubes ranging from a spark-like discharge to a green fluorescence of the glass wall.

The tubes are mounted on a frame approx. 40×47 cm² in size. The frame has a common connection with 4 mm sockets for the lower electrodes. On top, voltage is supplied by means of a probe with insulated handle.

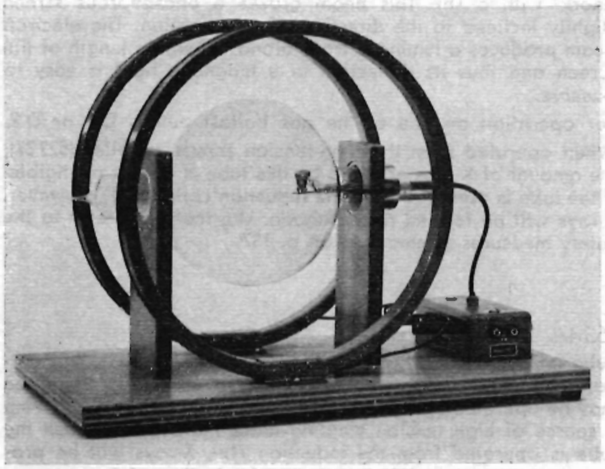
The sixth tube will not give rise to any detectable X-radiation when operated from the high-tension power supplies (522 37). If it is operated from the induction coil (521 11), however, X-rays originate at the anode. We therefore refer to the safety measures summarised on p. 137.



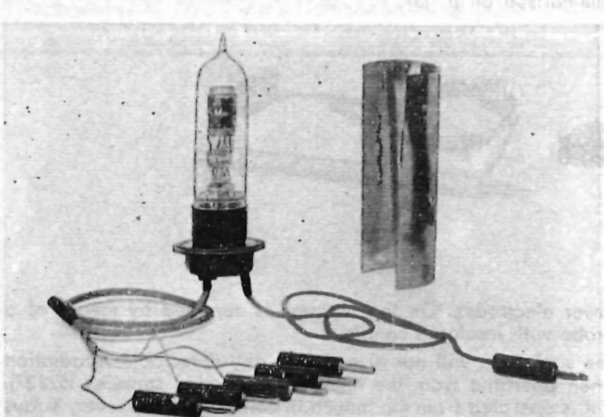
554 27



555 71



555 57 with 555 58

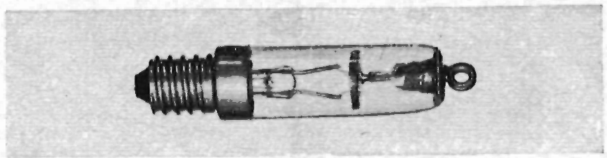


555 80

554 27
X-ray tube, with female ground joint NS 19/38; discharge tube for operation on the gas ballast pump D 1 or D 2.

555 71
X-ray tube, sealed discharge tube, dia. 100 mm.

For details and safety measures see section "Atomic Physics", p. 179.



554 55

554 55
Two-electrode tube for the Edison effect, for demonstrating the electric current produced by the thermionic emission of electrons from the filament of the tube. This tube may also be used for half-wave rectification. It has a thermionic cathode for 4 V, 5 A and an anode led out on top. The cathode is connected to an E 14 screw base.

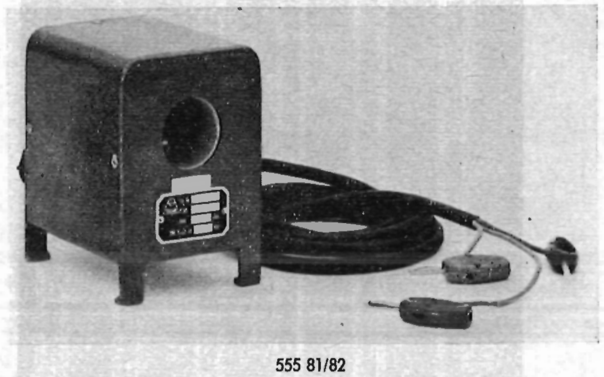
For setting up we recommend:

Socket E 14 on board	505 67
For detecting the current:	
Twin moving-coil instrument	442 73
or	
Demonstration multirange meter	531 86

555 57
Fine beam tube (gas-focussed tube), for determining the charge-to-mass ratio *e/m* of the electron, and for other experiments on the electrostatic and magnetic deflection of electron beams. We recommend using the base board with Helmholtz coils (555 58) for setting up the tube and making electric connections.

555 58
Base board with Helmholtz coils, for mounting the gas-focussed tube and making electric connections, and for producing a homogeneous magnetic field for the determination of *e/m*.

Details and the accessories required will be found in section "Atomic Physics" on p. 174.



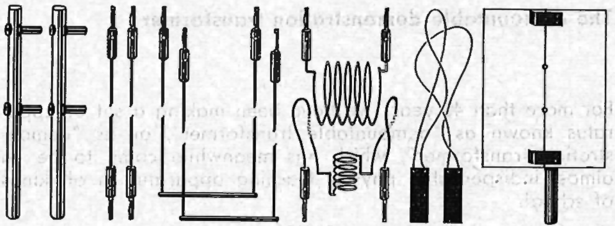
555 81/82

555 80
Franck-Hertz tube, for the observation of inelastic electron collisions. The tube is heated to 160° C in the electric oven (555 81 or 82) in the experiment. It has a 7-pin valve base which is inserted into the valve socket supplied with it. A shielded six-core cable leads from this socket to differently coloured leads with six plugs marked with letters.

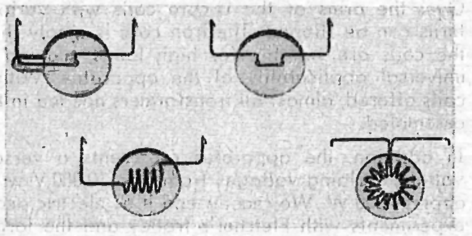
For more details see the section "Atomic Physics" on p. 178.

555 81
Electric oven, for 220 V, approx. 200 W, for the Franck-Hertz experiment, for radiation experiments and for experiments on temperature dependence. (See also the section "HEAT" on p. 61.)

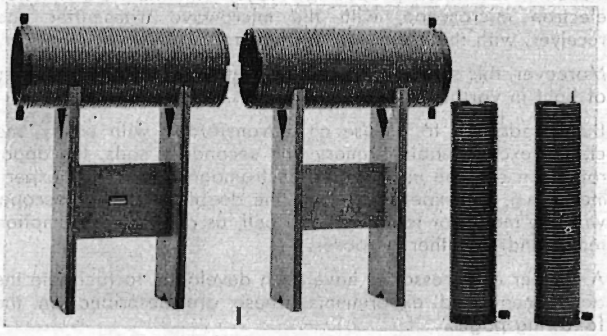
555 82
Electric oven, for 110 V; otherwise same as for Cat. No. 558 81.



560 15



442 64



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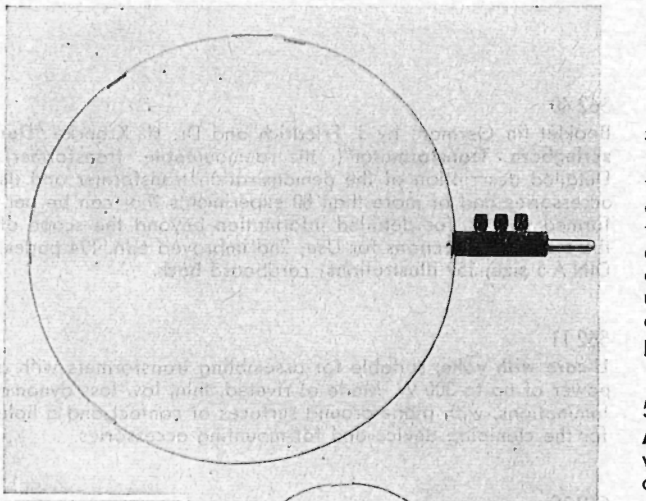

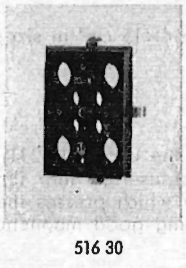

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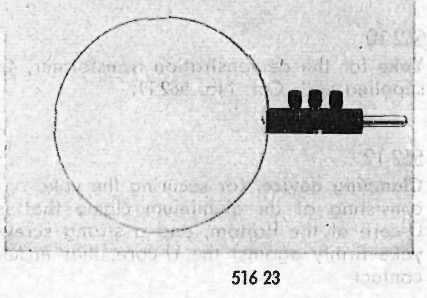


516 23

560 00

Equipment for experiments on electromagnetism, with stand material and magnetic components. Consists of various components for performing introductory experiments on electromagnetic phenomena: magnetic lines of force round current-carrying conductors, deflection of a magnetic needle in the field of a current-carrying conductor, forces between parallel current-carrying conductors, model of a moving-coil instrument and a moving-iron instrument, and others.

The set consists of: 2 holding rods with insulated sockets, 2 movable, flexible conductors with plugs, 1 rigid coil with plugs, 1 movable coil with plugs, 2 soft iron blocks with loops and 1 white plate with two holes.

The stand material comprises: 1 stand base (300 02), 1 stand rod, 75 cm long (300 43), 3 Leybold bosses (301 01), 1 small Bunsen clamp (302 62), 2 demonstration insulators (540 52) and 2 saddle bases (300 11).

The magnetic components are: 1 magnetic needle (513 11), 1 base for same (513 51), 1 horse-shoe magnet with yoke (510 21), 1 pair of bar magnets (510 12), and iron filings (514 73) with sifter-top jar (514 72).

560 15

Equipment for experiments on electromagnetism, without stand material and magnetic components, otherwise same as for Cat. No. 560 00.

442 64

Set of synthetic resin plates with conductors, for vertical projection on the base plate with connecting sockets (442 61). Four synthetic resin plates, dia. approx. 50 mm, with sealed-in copper wires in the shape of a single straight conductor, two straight conductors, one solenoid and one toroid. In order to demonstrate the lines of force, the plates are strewn with iron filings and a voltage of 1 V is applied briefly, causing a current of approx. 15 A to pass through the conductors.

Suitable sources of current are:

Demonstration transformer	562 11/12/15/18
or	
Accumulator	522 73

In addition, we recommend:

Iron filings	514 73
Sifter-top jar for iron filings	514 72

516 22

Set of solenoids, for use with the torsion balance (516 01) and for producing a homogeneous magnetic field. The solenoids can be used to demonstrate the dependence of the magnetic field inside an extended solenoid upon the intensity of the current, the number of turns/cm, and its independence of the cross-sectional area of the coil. Moreover, the coils can be used for quantitave induction experiments, and for constructing oscillatory circuits.

Further details will be found on p. 113.

516 23

Accessories for demonstrating Biot and Savart's law, for use with the torsion balance (516 01). Can be used to determine the dependence of the magnetic field at the centre of a circular current-carrying conductor as a function of the intensity of the current, the number of turns, and the diameter of the circle.

More details will be found on p. 113.

516 30

Wattmeter- and probe-coil, for use with the torsion balance (516 01) and for assembling an electrodynamic wattmeter, as well as for determining the permeability of free space with the help of a ballistic galvanometer. More details will be found on p. 113.

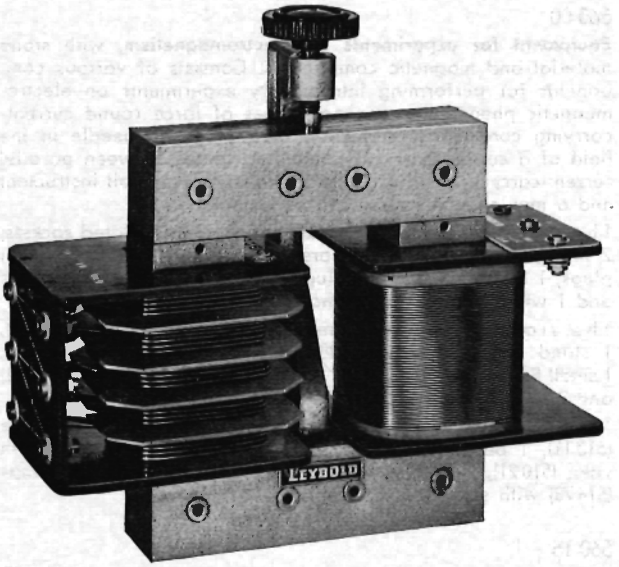


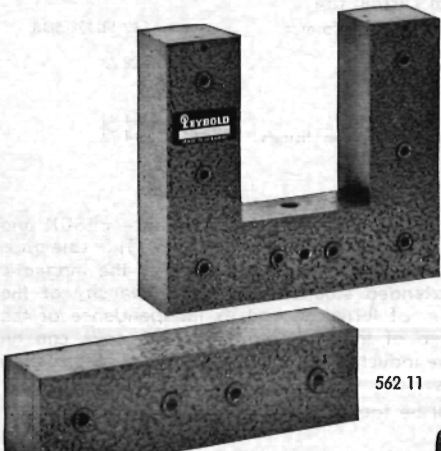
Fig. 83 PH 2045

Demonstration transformer for converting mains voltage of 220 V to low voltage.

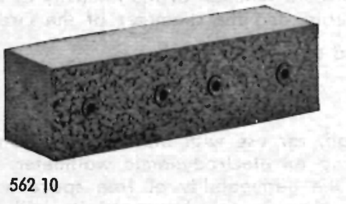
The transformer as shown is assembled from the following parts:

U-core with yoke	562 11
Clamping device	562 12
Coil with 500 turns	562 14
Coil with 46 turns	562 18

This combination is suitable for producing voltages of 2 to 20 V, with 2-V tappings. When the mains coil (562 21) with cable (501 97) is used as primary coil, the transformer is absolutely safe to touch. Other voltages and applications may be obtained by using other coils.



562 11



562 10

562 12

The demountable demonstration transformer

For more than 40 years we have been making a set of apparatus known as "demountable transformer", or as "demonstration transformer", which has meanwhile come to be an almost indispensable physics teaching apparatus in all kinds of school.

This transformer consists of a U-shaped core and a yoke, both made from laminated sheet-iron.

Over the arms of the U-core coils with various numbers of turns can be slipped. The iron core is amply dimensioned and the coils are suitable for high loads, making for an almost universal applicability of the apparatus. With the range of coils offered, almost all transformers needed in teaching can be assembled.

In addition, the apparatus represents a versatile source of voltage yielding voltages from 1 to 10,000 V with an output of approx. 300 W. We recommend it as electric accessory, e.g. for experiments with Fletcher's trolley and the large electric stop clock, with the wave trough and the wave generator, with the induction coil when producing X-rays, with the field-emission electron microscope, with the microwave transmitter and receiver, with the Tesla coil and others.

Moreover, this source of voltage is useful for supplying sources of light in various optical experiments, and for projection.

But in addition to its use as a transformer with easily and clearly exchangeable primary and secondary coils, the apparatus can also be used as an electromagnet for many experiments, e.g. for experiments with the double-loop oscilloscope, with the model of telegraph and bell, as an A.C. consumption meter and for other purposes.

A number of accessories have been developed to facilitate the above-mentioned experiments. These are described on the following pages.

562 40

Booklet (in German) by J. Friedrich and Dr. H. Kröncke **"Der zerlegbare Transformator"**(the demountable transformer). Detailed description of the demonstration transformer and its accessories and of more than 80 experiments that can be performed with it, for detailed information beyond the scope of the ordinary Directions for Use; 2nd improved edn. 194 pages, DIN A 5 size, 159 illustrations; cardboard back.

562 11

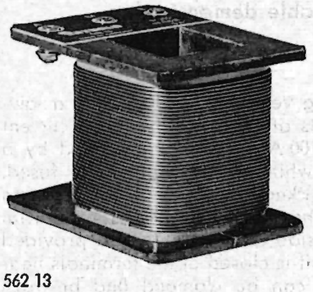
U-core with yoke, suitable for assembling transformers with a power of up to 300 W. Made of riveted, thin, low-loss dynamo laminations, with plane-ground surfaces of contact and a hole for the clamping device and for mounting accessories.

562 10

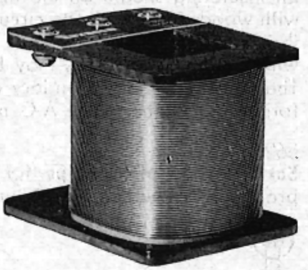
Yoke for the demonstration transformer, 4×4×15 cm^3 in size; supplied with Cat. No. 562 11.

562 12

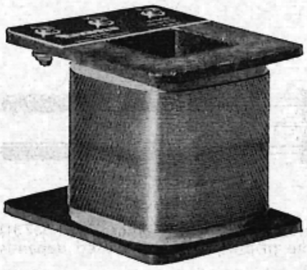
Clamping device, for securing the yoke on the U-core (562 11), consisting of an aluminium clamp that is inserted into the U-core at the bottom, and a strong screw which presses the yoke firmly against the U-core, thus ensuring good magnetic contact.



562 13



562 14



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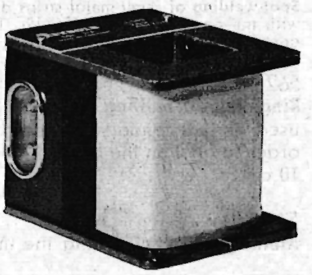
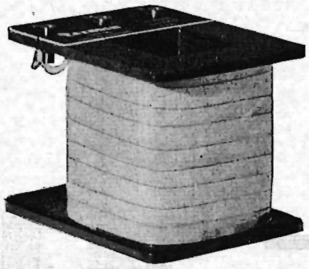


562 21



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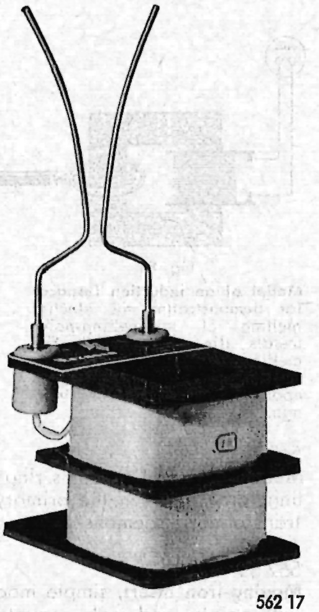

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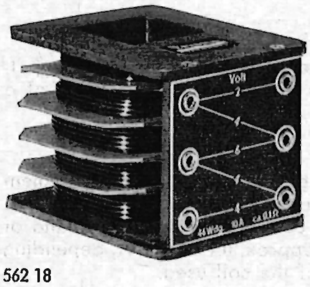


562 18

Coils for the demountable demonstration transformer

These coils consist of strong moulded plastic coil formers, possessing excellent insulating properties, with square centre holes for slipping them on the arms of the U-core, and varnished copper wire windings of various numbers of turns and wire thicknesses.

The beginning, centre and end of the windings are connected to 4 mm sockets. The number of turns, the D.C. resistance and the maximum admissible current under continuous load are stated on the coil formers. A current several times greater than the maximum permissible continuous load may be passed briefly.

562 18

Coil with 46 turns. This coil can be used to assemble a very useful source of low tension. Depending upon the available mains voltage, and the primary coil used, various secondary voltages can be obtained. The maximum permissible continuous load is 10 A, but the coil can perfectly safely be short-circuited, provided it is switched off again before it has heated up overmuch.

The coil is provided with 6 sockets on its front face which can be combined with one another in any desired manner, to obtain 10 different voltage values.

When used with one of the rectifiers (523 71–73) the transformer with this coil will constitute a source of D.C.

562 21

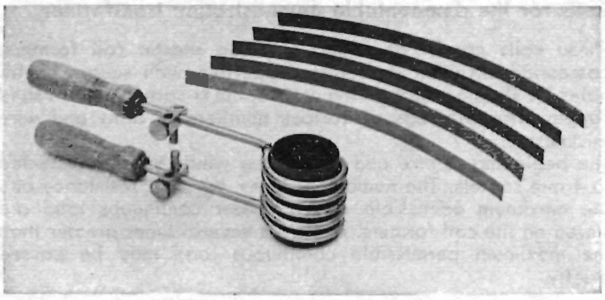
Protected mains coil with 500 turns, for 220 V mains, safe to touch, particularly suitable for student's practical work. This coil has the same electrical data as Cat. No. 562 14; but it is provided with additional insulation, and live parts are nowhere accessible. Instead of connecting sockets, this coil is provided with a male mains socket.

A mains lead with female apparatus plug and switch (501 97) must be used to connect this coil (562 21) to the mains.

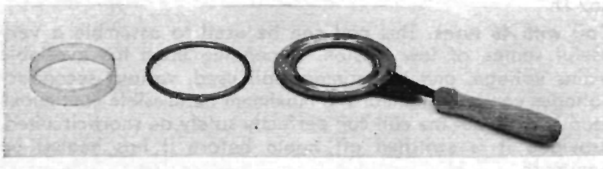
Coil Cat. No.	No. of turns	Max. continuous load A	D.C. resistance Ω	Wire dia. mm
562 13	250	5	approx. 0.6	1.5
	Primary coil for 110 V; also for electromagnet			
562 14	500	2.5	approx. 2.5	1.0
	Primary coil for 220 V (occasionally also for 110 V)			
562 21	500	2.5	approx. 2.5	1.0
	Protected primary coil for 220 V (occasionally also for 110 V)			
562 15	1,000	1.25	approx. 12	0.7
	Primary coil for 220 V and low powers; also as series choke for spectrum lamps			
562 16	10,000	0.1	approx. 1,600	0.2
562 17	23,000	0.02	approx. 16,000	0.1
	With impregnated winding; supplied complete with horn-shaped spark electrodes			
562 18	46	10	approx. 0.08	2.0
	Secondary coil for low-tension transformer			

Low-tension transformer with 46 turn secondary coil:

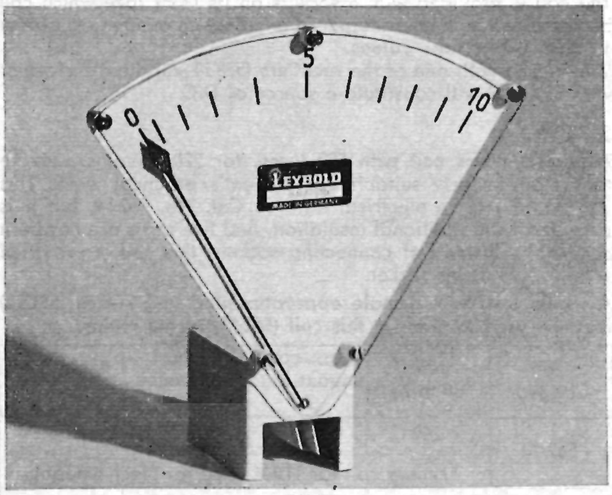
Primary voltage	Primary coil	Secondary voltage	In steps of
110 V	250 turns	20 V	2 V
	500 turns	10 V	1 V
	1,000 turns	5 V	0.5 V
220 V	500 turns	20 V	2 V
	1,000 turns	10 V	1 V



562 19 562 31



562 33 562 32 562 20



562 35

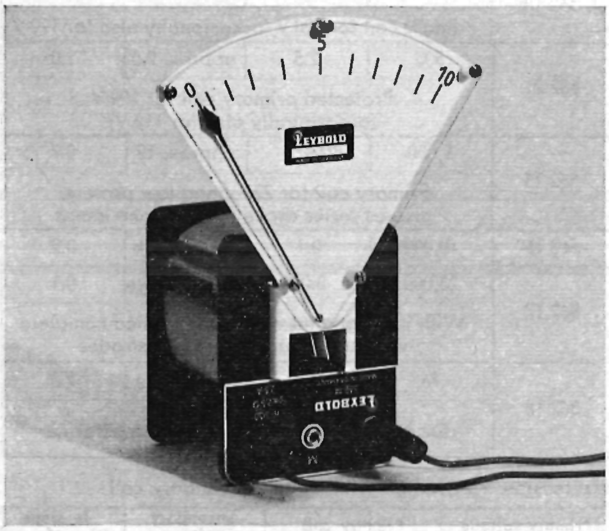


Fig. 87 PH 2053

Fig. 87
Moving-iron instrument, consisting of the moving-iron insert (562 35) and the 250 turn coil of the demountable transformer. Range approx. 4 A; for other ranges, use coils with other numbers of turns.

Accessories for the demountable demonstration transformer

562 19
Coil with 5 turns, for producing very heavy currents in a low-resistance circuit. Measurements of the intensity of the current showed a current of several 100 A when short-circuited by a thick iron nail which became white-hot and ultimately fused. Round copper rods of 8 mm thickness are bent to form 5 turns of approx. 65 mm diameter. The coil so formed is lined with an insulating sheath on the inside and the ends are provided with wooden handles. The circuit is closed at the terminals near the handles, into which nails can be clamped and between which sheet-metal strips may be inserted.
The coil is used as secondary coil on the demonstration transformer connected to the A.C. mains on its primary side.

562 31
Set of 5 sheet-metal strips, for demonstrating the spot-welding process with the coil with 5 turns (562 19).

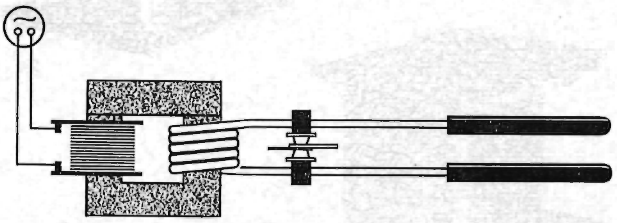


Fig. 84
Spot-welding of sheet-metal strips of up to 0.75 mm thickness (e.g. 562 31) with the coil with 5 turns (562 19). The primary coil to be used depends upon the available mains voltage.

562 20
Ring-shaped melting ladle, with wooden handle which can be used as a secondary coil on the demonstration transformer in order to explain the principle of induction melting; dia. approx. 10 cm.

562 32
Melting ring (tin), fitting the melting ladle (562 20).

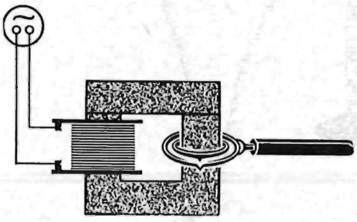


Fig. 85
Model of an induction furnace. for demonstrating the electric melting of low-melting-point metals (tin solder) with the melting ladle (562 20). The primary coil to be used depends upon the available mains voltage.

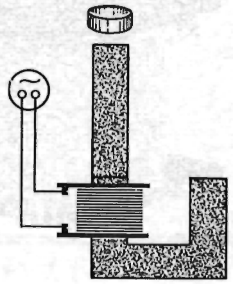


Fig. 86
Thomson's ring experiment with the metal ring (562 33) and a primary coil chosen to suit the available mains voltage.

562 33
Metal ring, for Thomson's ring experiment by which the repelling force between the primary and secondary windings of a transformer is demonstrated.

562 35
Moving-iron insert, simple model of a moving-iron instrument with pointer and scale, mounted on a frame that fits the coils 562 13 to 562 18. This instrument constitutes the simplest kind of ammeter, with ranges between approx. 0.1 and 20 A, depending upon the number of windings of the coil used.

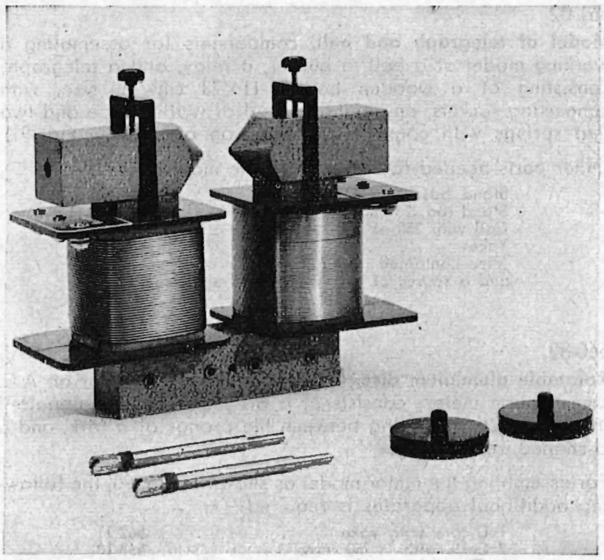
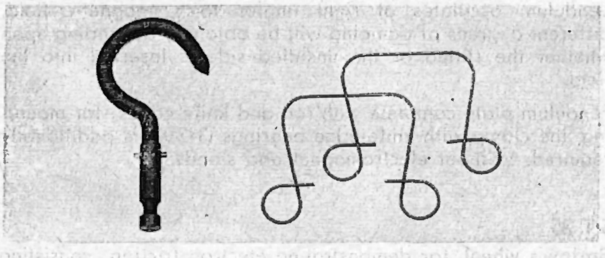


Fig. 88 PH 2052

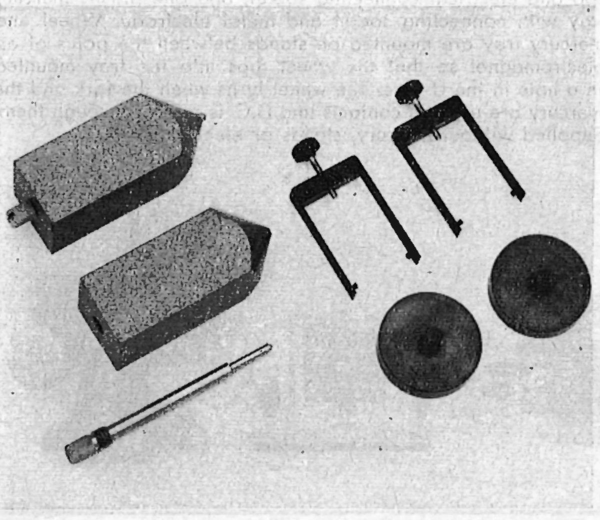
High-intensity electromagnet, assembled from separate components and suitable for all experiments requiring a homogeneous or inhomogeneous magnetic field.

The following components are required for assembly:

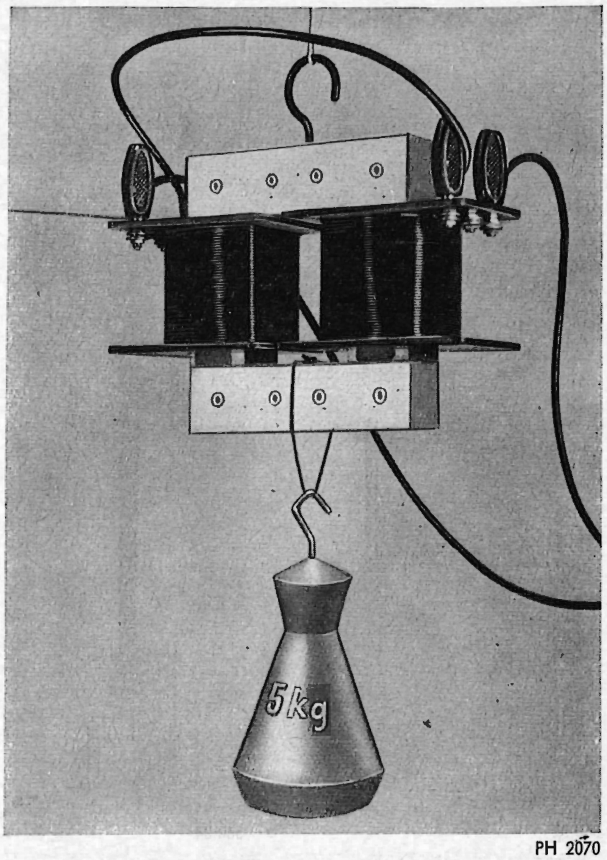
1 U-core . . . . from	562 11
2 Coils with 250 turns	562 13
1 Pair of pole-pieces	560 31
1 Source of D.C. yielding approx.. 10 V, 10 A	



560 29



560 31



PH 2070

Fig. 89

Electromagnet able to lift large weights, energised by D.C. of approx. 5 A; this magnet can also be used to demonstrate the remanence (residual magnetisation) of the iron core.

Assembled from:

1 U-core with yoke	562 11
2 Coils with 250 turns	562 13
1 Fastening hook and two spring clamps	560 29
in addition:	
1 Weight with hook, 5 kg	388 24

560 29

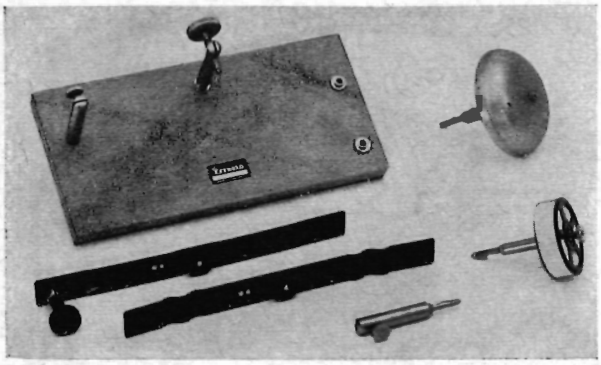
Fastening hook and spring clamps, for assembling an electromagnet from demonstration transformer parts. The hook is inserted into a hole in the U-core. The magnet is suspended from it with its arms pointing downwards. The spring clamps retain the coils.

560 31

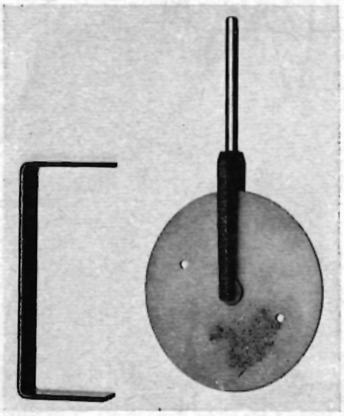
Pair of bored pole pieces, for assembling an electromagnet from demonstration transformer parts. This assembly has been found highly effective and useful in a number of important experiments, e.g. with v. Waltenhofen's pendulum, Barlow's wheel, for demonstrating diamagnetism and paramagnetism, the deflection of β-rays in a magnetic field, and other experiments.

Soft-iron pole pieces, 10 cm long, cross-sectional area 4×4 cm²; with longitudinal bore. Each pole-piece has one conical and one flat end for producing inhomogeneous and homogeneous magnetic fields, respectively.

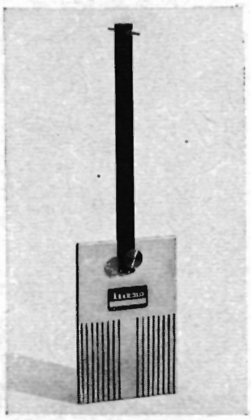
The following accessories are included: 2 soft-iron inserts for the longitudinal bores, 2 additional pole-pieces that can be screwed on to produce homogeneous magnetic fields, and two clamps for mounting the pole-pieces on the arms of the U-core.



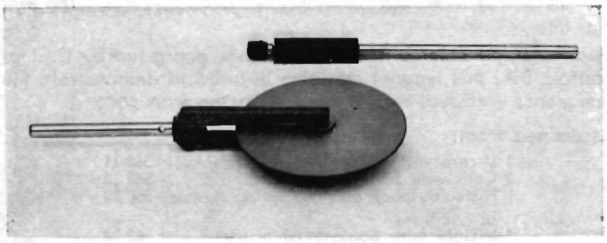
561 02



560 32



560 34



560 35

The electromagnet needed for the experiments with Waltenhofen's pendulum (560 34) and Barlow's wheel (560 35) is shown in Fig. 88.

The following parts are needed for assembling the magnet:

1 U-core	from 562 11
2 Coils with 250 turns	562 13
1 Pair of pole-pieces	560 31
1 Source of D.C. yielding approx. 10 V, 5 A	

561 02

Model of telegraph and bell, components for assembling a working model of a bell, a buzzer, a relay, and a telegraph; consisting of a wooden board, 11×23 cm² in size, with connecting sockets, one bell, one reel of writing tape and two leaf springs with contacts and soft-iron plates (see Fig. 91).

Other parts needed for assembling the models:

Stand base	300 02
Stand rod, 25 cm long	300 41
Coil with 250 or 500 turns	562 13 or 14
Yoke (also contained in 562 11)	562 10

and a source of current yielding approx. 6 V D.C.

560 32

Rotatable aluminium disc, for assembling a model of an A.C. consumption meter; consists of a disc, dia. 15 cm, supported in a low-friction bearing between the prongs of a fork, and a U-shaped iron stirrup.

For assembling the meter model as shown in Fig. 90, the following additional apparatus is required:

1 U-core with yoke	562 11
2 Coils with 250 turns	562 13
1 Coil with 10,000 turns	562 16
1 Rheostat, 320 Ω	537 23
Stands as required	

A detailed discussion of this meter model and the measurements that can be performed with it will be found in the book: Friedrich-Kröncke, "Der zerlegbare Transformator" (in German), 562 40.

560 34

Waltenhofen's pendulum, for eddy current experiments, consisting of two parts: one metal plate, 10×7 cm² in size, laminated on one side by means of slits, and one rod in which this plate is held, with kife-edge for low-friction suspension. If the pendulum oscillates at right angles to a magnetic field, different degrees of damping will be obtained depending upon whether the slitted or the unslitted side is inserted into the field.

Pendulum plate complete with rod and knife-edges; for mounting, the clamp with knife-edge bearings (342 07) is additionally required. Without electromagnet and stands.

560 35

Barlow's wheel, for demonstrating electron friction; consisting of a copper disc, dia. approx. 12 cm, supported in a low-friction bearing between the prongs of a fork, with supporting rod and electrical connecting socket, and one plastic mercury tray with connecting socket and metal electrode. Wheel and mercury tray are mounted on stands between the poles of an electromagnet so that the wheel dips into the tray mounted in a hole in the U-core. The wheel turns when the fork and the mercury are used as contacts and D.C. is passed through them. Supplied without mercury, stands or electromagnet.

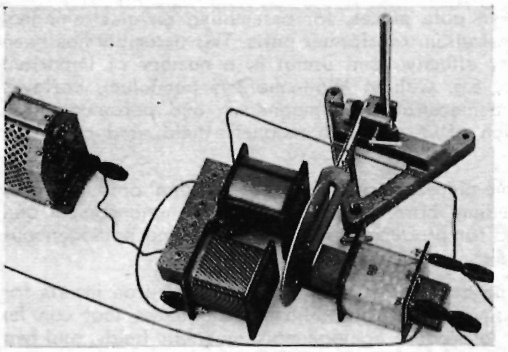


Fig. 90 Model of an A.C. consumption meter PH 2071

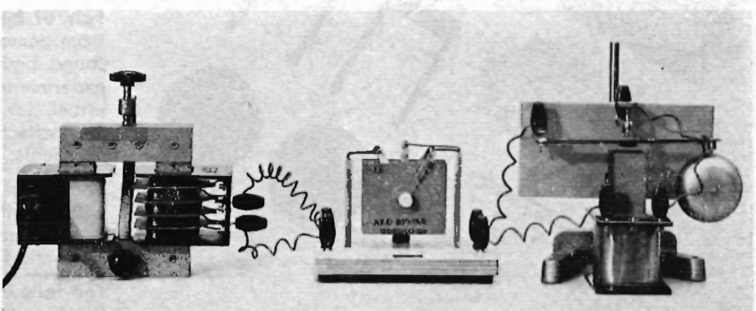
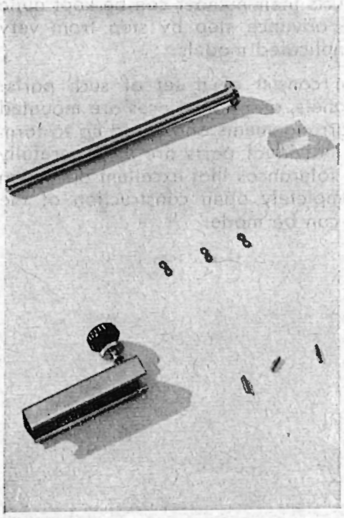
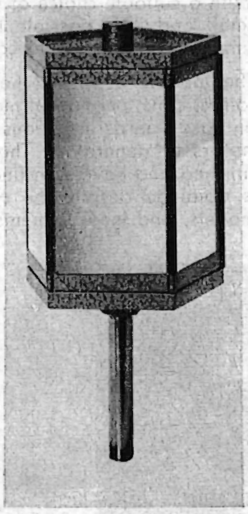


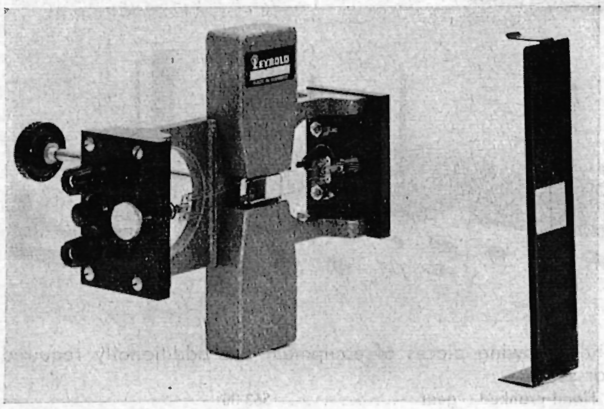
Fig. 91 Model of an electric bell PH 2072



560 48
560 41



504 96



560 43

504 96
Rotary mirror on rod, for individual observation of periodic processes, e.g. the lighting-up of glow lamps in A.C. operation, and for projection of stationary wave-forms, e.g. when making A.C. experiments with the double wire-loop oscilloscope (560 43).

Five-sided mirror, the faces of which are 50×80 mm² in size, mounted in a solid cast-iron mount and carefully adjusted to make the reflected images produced by the different surfaces agree with each other with great accuracy. On rod, dia. 10 mm, approx. 85 mm long. A suitable variable speed rotator is the standard electric motor (347 25/26).

560 41
Apparatus for experiments on para- and diamagnetism, for studying the effects of an inhomogeneous magnetic field on ferro-, dia-, and paramagnetic substances. The set contains 3 rods, each of 9 mm length, made of nickel, bismuth, and aluminium, each with one suspension thread, and one sprung holder from which the samples are suspended between the poles of an electromagnet. Without electromagnet (see Fig. 88) and stands.

560 48
Apparatus for demonstrating the rotation of the plane of polarisation, to demonstrate the phenomenon known as the "Faraday-effect". The plane of polarisation of plane-polarised light is rotated in a glass rod if a magnetic field is applied parallel to the direction of propagation of the light.

The equipment consists of a rectangular flint glass rod, 10×10×20 mm³ in size, with polished end faces, and a small platform on which the glass rod is laid. For the experiment, the stem of the platform is inserted into the hole in the U-core, the glass rod is laid between the conical ends of the bored pole pieces, and polarised light passed through the bores and the glass rod.

For producing and analysing the polarised light a lamp-house (450 60) with lamp (450 51) and single-lens condenser (460 17) in position, a pair of polarising filters (472 40) and a projection lens, f = 100 mm (460 03), are mounted on one of the small optical benches (460 41 or 460 42 or 460 43) using 5 Leybold bosses (301 01) as saddle bases. The coils are briefly overloaded in this experiment.

The electromagnet required for the experiments on para- and diamagnetism and for rotating the plane of polarisation is shown in Fig. 88.

It is assembled from the following parts:

1 U-core	from 562 11
2 Coils with 250 turns	562 13
1 Pair of pole-pieces	560 31
1 Source of D.C. yielding approx. 20 V, 10 A	

560 43
Double wire-loop oscilloscope, for studying the wave-forms of electrical oscillations; 50 c/s A.C. is particularly suitable. The two mutually independent loops of the oscilloscope can produce two wave-forms simultaneously using a rotary mirror, so that, for instance, A.C. phase-shifts with different kinds of load can be rendered visible.

The apparatus is constructed as an accessory to the U-core (562 11). It is equipped with two pole-pieces fitting this core, with holding screw. Each of the two systems consists of one wire loop with concave mirror, adjusting facilities, and connecting sockets. They are suspended between the two pole-pieces. The natural frequency of the loops is about 20 c/s. Complete with coloured windows for distinguishing the beams of light reflected from the mirrors of the two loops.

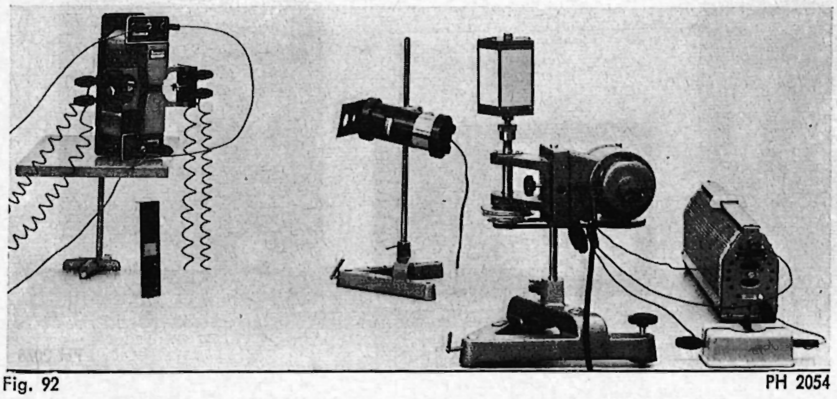


Fig. 92
PH 2054

Fig. 92
Assembly of the double wire-loop oscilloscope

We recommend using the following pieces of apparatus:

1 U-core	from 562 11
2 Coils with 250 turns	562 13
For illumination and projection of the spots of light:	
Illuminating device	516 02
The horizontal time-base deflection is brought about by a rotary mirror.	
We recommend	
Rotary mirror	504 96
Standard electric motor	347 25/26
For 220 V mains voltage:	
Rheostat, 320 Ω	537 23
For 110 V mains voltage:	
Rheostat, 110 Ω	537 24
Stands	
Connecting leads	

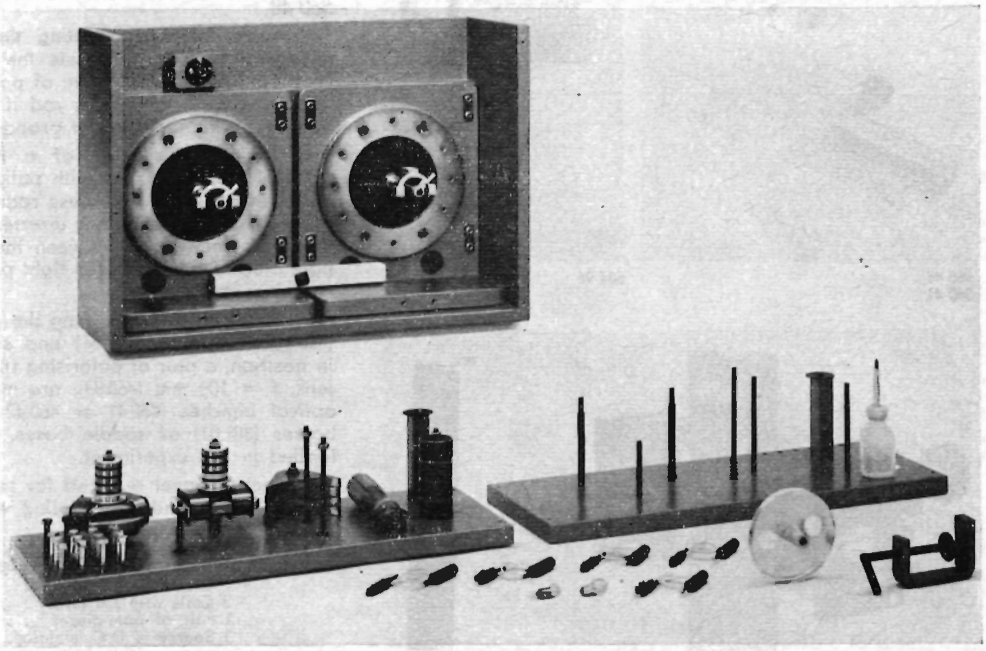
Models of electric motors and generators for classroom experiments

The treatment of electric motors and generators in teaching requires not so much true-to-life models of actually used machines, which are generally rather obscure and confusing in their layout, but rather clearly constructed models in which the working principle and basic construction of electrical machines can be studied. In view of the great variety of designs met with in electric machines it is advantageous to assemble the models from interchangeable separate parts. With a suitable choice of parts their number can be kept quite small and it is possible to advance step by step from very simple arrangements to complicated models.

The models described here consist of a set of such parts: rotors, coils, permanent magnets, and pole pieces are mounted on base boards in various arrangements and wired up to form motors or generators. The individual parts are very carefully finished and have such fine tolerances that excellent operation is obtained despite the completely open construction of the models, and measurements can be made.

Models of electric motors and generators

Set I (563 00)



563 00

Set I provides an easily comprehensible introduction into the field of electric motors and generators. It is possible to show simultaneously in one arrangement the transformation of mechanical work into electrical energy, and the transformation of the electrical energy back into mechanical work.

Models of the following machines can be assembled among others: D.C. motor – D.C. generator – A.C. generator – synchronous motor – three-phase external-pole generator. Experimenting instructions are supplied with the set.

The magnetic fields of the motors and generators are produced by means of permanent magnets. The construction and working mechanism of brushes, slip rings, commutators and two- and three-pole rotors can be show in a simple and clear manner.

The following pieces of equipment are additionally required for set I:

1 Hand-cranked gear	563 30
or:	
1 Electric driving motor, 220 or 110 V	563 35 or 36
1 Lamp, 24 V	505 18
Source of current for low-tension D.C., e.g.	
Demonstration transformer	562 11/12/18, and for 220 V A.C. 562 14, or 562 21 with 501 97, or, for 110 V A.C., 562 13
with rectifier	523 71
1 Measuring instrument for D.C. and A.C.	531 56 or 531 86
Elastic connecting leads	501 89/90/91
or:	
Coloured connecting leads	501 20–39

More details will be found in the brochure VA 7 E: "Manual of Experiments with Models of Electric Motors and Generators" (599 127).

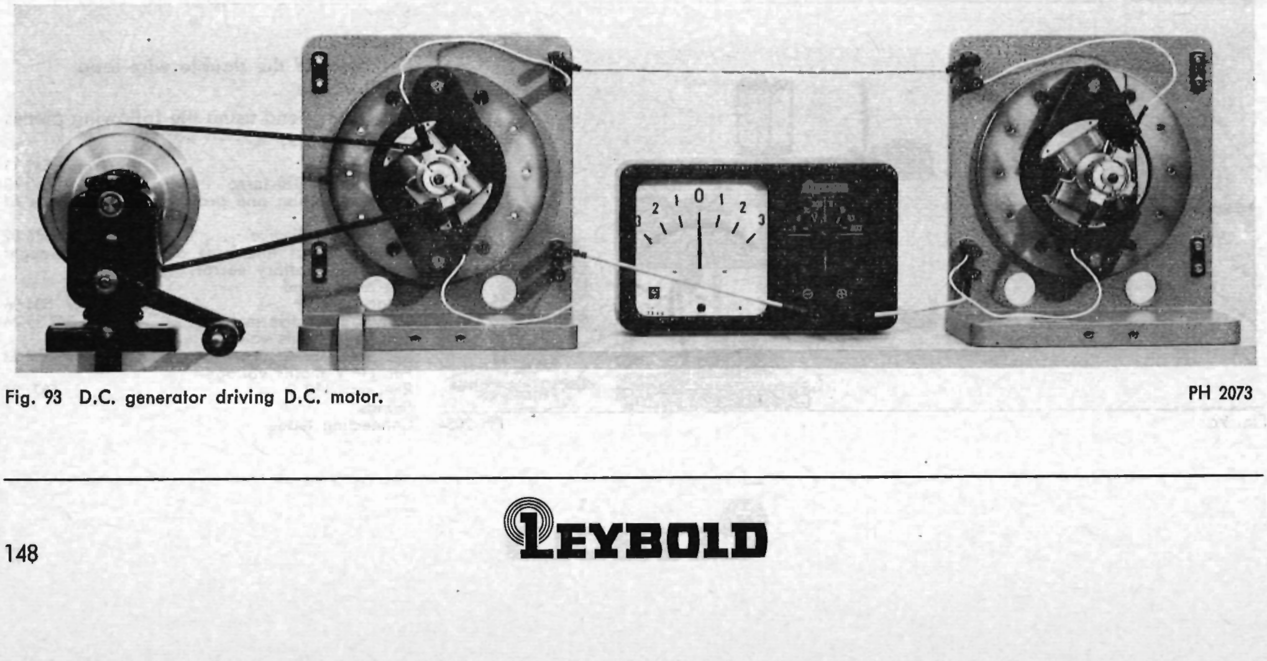
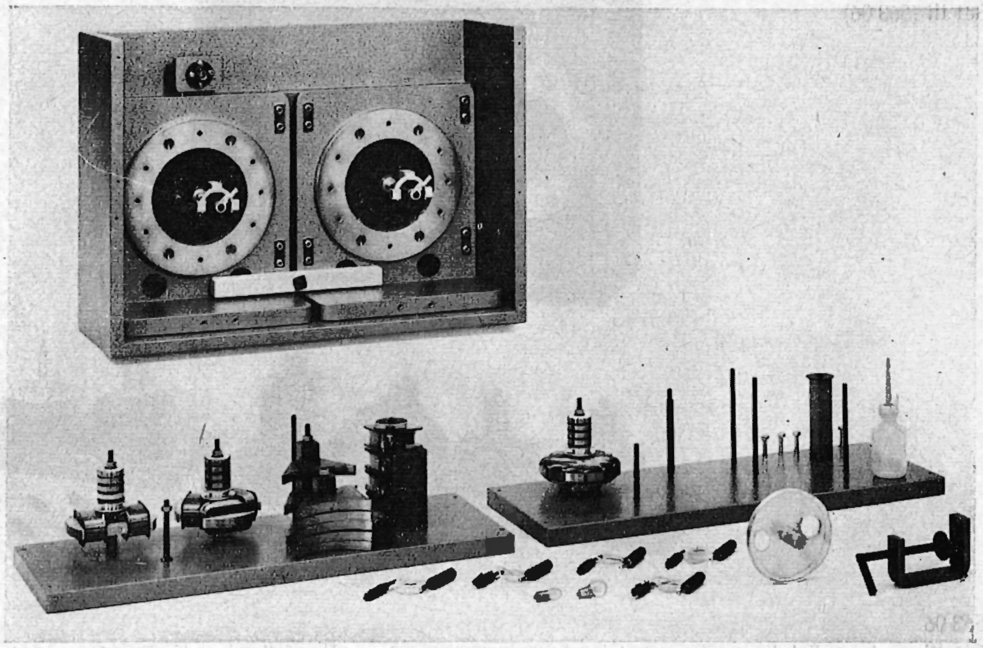


Fig. 93 D.C. generator driving D.C. motor.

PH 2073

Models of electric motors and generators
Set II (563 03)



563 03

Set II contains Set I and extends its scope by the introduction of a drum rotor and of coils for exciting the magnetic field, and as induction coils for the internal pole generators. With this set all the experiments that are possible with Set I can be performed, and, in addition, series-wound and shunt-wound machines with commutators and separately excited and self-excited generators, in particular, can be assembled, as well as the better operation of a twelve-pole armature with twelve-pole commutator demonstrated.

The following models, among others, can be demonstrated in addition to those described under Set I:

Separately excited and self-excited generators
D.C. motors, shunt-wound and series-wound,
A.C. motor
Three-phase synchronous motor
Three-phase external pole generator
Three-phase internal pole generator
Rotary converter
Repulsion motor

For the use of Set II, the following parts are additionally required:

1 Hand-cranked gear	563 30
or:	
1 Electric driving motor, 220 or 110 V	563 35 or 36
1 Three-pole lever switch with 3 lamp sockets E 10	563 32
3 Lamps, 24 V	505 18
1 Measuring instrument for D.C. and A.C.	531 56 or 531 86
Source of current for D.C. and A.C., e.g.	
Demonstration transformer	562 11/12/18, and for 220 V A.C. 562 14, or 562 21 with 501 97, or, for 110 V A.C., 562 13
with rectifier	523 71
Elastic connecting leads	501 89/90/91
or:	
Coloured connecting leads	501 20–39

The three-phase synchronous motor requires a low-tension three-phase supply of 6–10 V.

Experimenting instructions are supplied with the set.

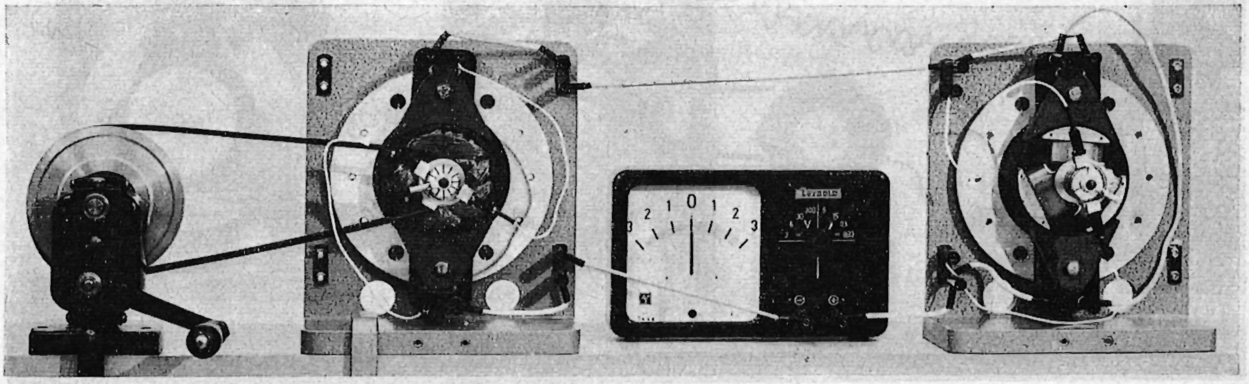
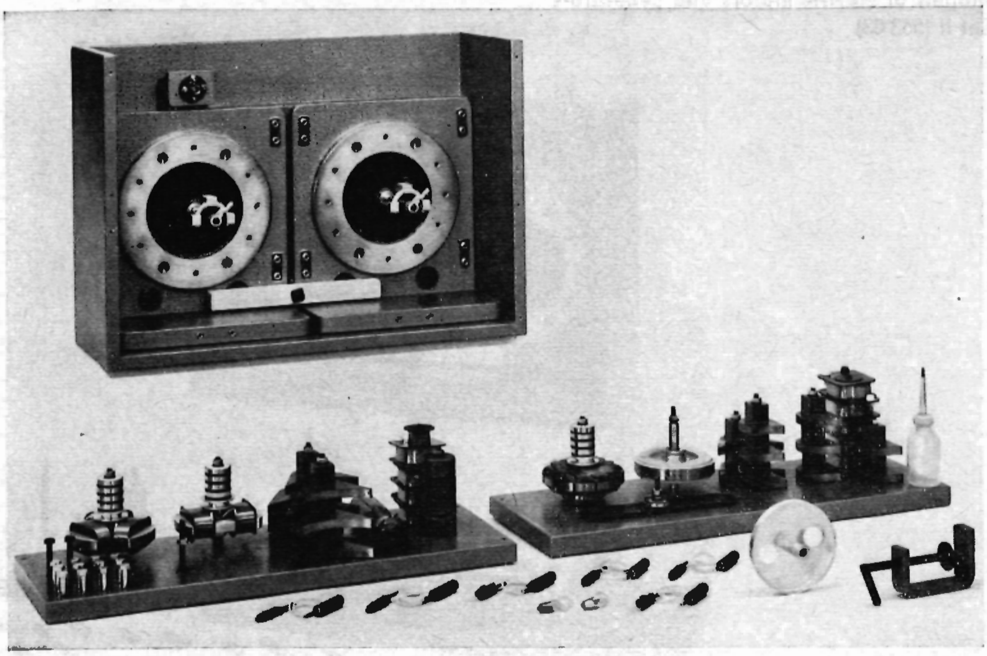


Fig. 94 Self-excited series-wound D.C. generator driving shunt-wound D.C. motor. PH 2074

Models of electric motors and generators

Set III (563 06)



563 06

Set III contains Set II supplemented by further components. This set affords an introductory insight into the diverse practical embodiments of the principles of electric generators and motors. In particular, rotating-field and induction motors can be demonstrated. Short-circuited rotors and narrow pole-pieces permit the building and operation, among others, of the following models not included in Sets I and II:

- Two-pole induction motor (non-self-starting)
- Self-starting induction motor with inductive or capacitive auxiliary phase
- Three-phase induction motors with 3 or 6 poles
- Split-pole motor (pole pieces with one-sided short-circuit winding)

Experimenting instructions are supplied with the set.

The following pieces of apparatus are additionally required for the use of Set III:

1 Hand-cranked gear	563 30
or:	
1 Electric driving motor, 220 or 110 V	563 35 or 36
3 Lamps, 24 V	505 18
1 Three-pole lever switch with 3 lamp sockets E 10	563 32
1 Measuring instrument for D.C. and A.C.	531 56 or 531 86
Source of current for D.C. and A.C., e.g.	
Demonstration transformer	562 11/12/18, and for 220 V A.C. 562 14, or 562 21 with 501 97, or, for 110 V A.C., 562 13
with rectifier	523 71
Elastic connecting leads	501 89/90/91
or:	
Coloured connecting leads	501 20–39

For the three-phase motors, low-tension three-phase current is needed.

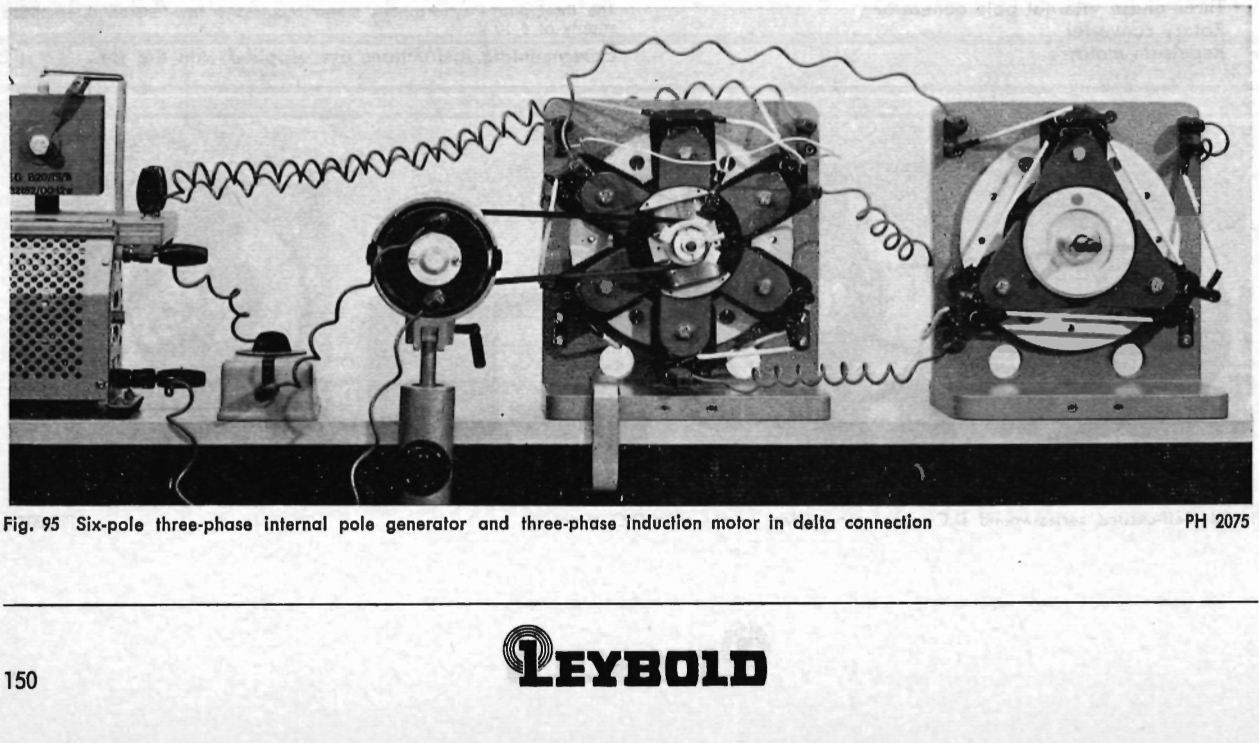
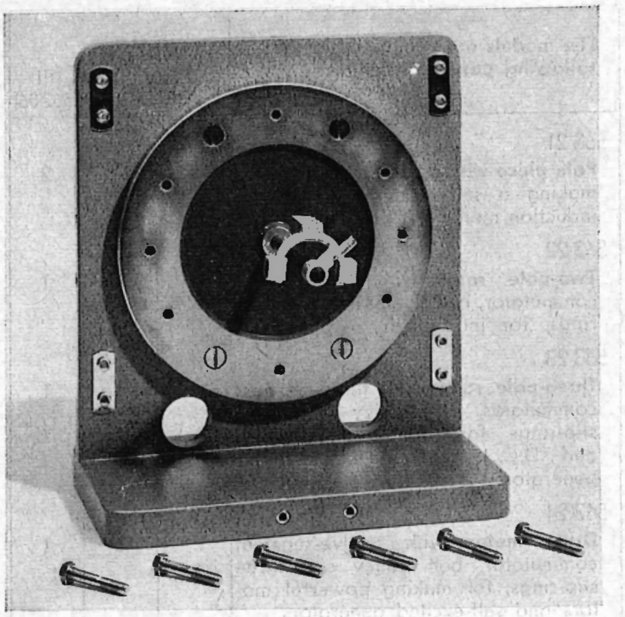
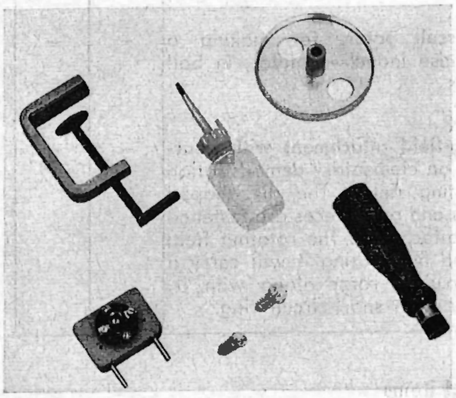


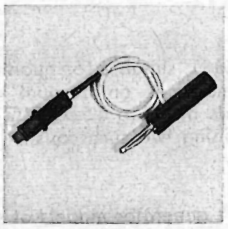
Fig. 95 Six-pole three-phase internal pole generator and three-phase induction motor in delta connection PH 2075



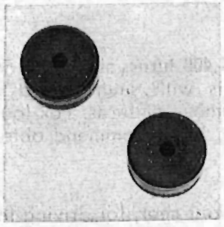
563 26



563 27



563 13

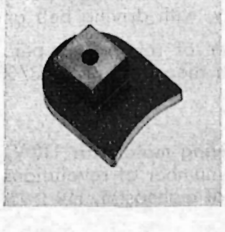


563 19

563 11

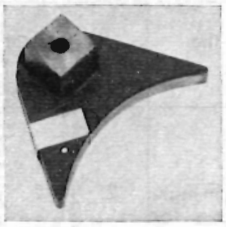
563 09

563 10

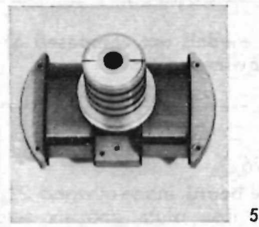


563 20

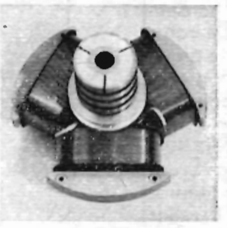
The models are composed of the following parts:	In set		
	I (563 00)	II (563 03)	III (563 06)
563 26 **Base board,** made of wood, 22 cm high, with iron plate and six screws for fastening the pole pieces. A hardened, polished axle receiving the rotor is provided at the centre of this plate. Four pairs of 4 mm sockets for connecting the leads and 4 pairs of sockets for fastening the lamp socket are provided on the outside. This item moreover includes a rocking brush holder to receive two commutator brushes or three slip-ring brushes (also supplied separately under Cat. No. 563 18).	2	2	2
563 27 **The accessories for the base board** comprise: oil can, monkey wrench, lamp socket E 10 with connecting sockets and plugs, 6 V lamp (also supplied separately under Cat. No. 505 12), centring disc (also supplied separately under Cat. No. 563 17) and bench clamp.	1	1	1
563 13 **Brush,** for the supply and collection of current on collectors and slip-rings; high-grade carbon brushes, spring mounted, with 25 cm long cable and plug. For loads up to 1.5 A.	5	5	6
563 19 **Pair of disc-shaped magnets,** for producing permanent magnetic fields.	2	2	2
563 11 **Coil with 250 turns,** for electric excitation of magnetic fields and as induction coil for internal-pole machines, for loads up to 1.5 A; D.C. resistance 1.8 Ω, with two insulated 4 mm sockets.	–	4	9
563 09 **Wide pole piece without spigot,** for use with the disc-shaped magnets in D.C. and A.C. machines with permanent magnets.	4	4	4
563 10 **Wide pole piece with spigot,** for receiving the coils, for two- and three-pole machines.	–	4	6
563 20 **Narrow pole piece with spigot,** for receiving the coils in 4- and 6-pole machines, and for reversing poles.	–	–	8



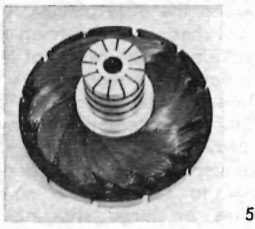
563 21



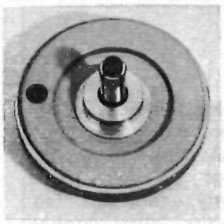
563 22



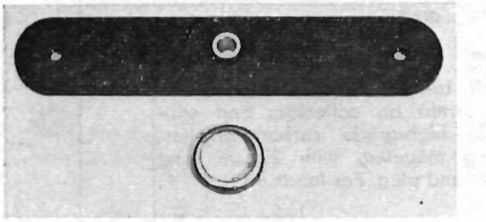
563 23



563 24

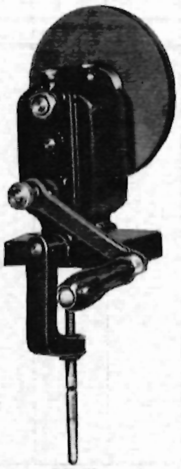


563 12

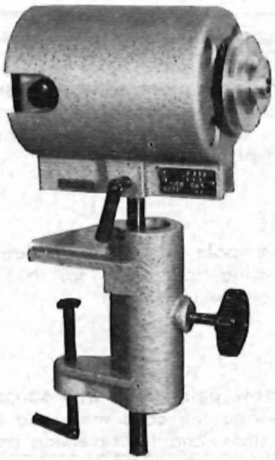


563 25

563 14



563 30



563 35

The models are composed of the following parts:	In set		
	I (563 00)	II (563 03)	III (563 06)
563 21 **Pole piece with short-circuit loop,** for making a self-starting single-phase induction motor.	–	–	2
563 22 **Two-pole rotor** with two-segment commutator, belt pulley and two slip-rings, for introductory experiments.	1	1	1
563 23 **Three-pole rotor** with three-segment commutator, belt pulley and three slip-rings for self-starting motors and D.C., A.C., and three-phase generators.	1	1	1
563 24 **Drum motor** with twelve-segment commutator, belt pulley and three slip-rings, for making powerful motors and self-excited generators.	–	1	1
563 12 **Short-circuit rotor,** for making a three-phase induction motor, in ball bearings.	–	–	1
563 25 **Rotating-field attachment with bearing,** for an elementary demonstration of rotating fields. The disc-shaped magnets and pole pieces are fastened to this attachment. The rotating field produced by rotating it will carry a short-circuited rotor along with it; complete with short-circuit ring.	–	–	1

Additional items

563 14

Coil with 1,400 turns, similar to 563 11, suitable for quantitative experiments with shunt-wound machines on account of the greater number of turns. For loads of up to 0.5 A; D.C. resistance 45 Ω. We recommend obtaining two such coils.

563 30

Hand-cranked gear, for driving the generator models at speeds of up to approx. 3,000 r.p.m.; complete with belt pulley, dia. 12 cm, bench clamp for fastening to a bench, and driving belt.

563 35

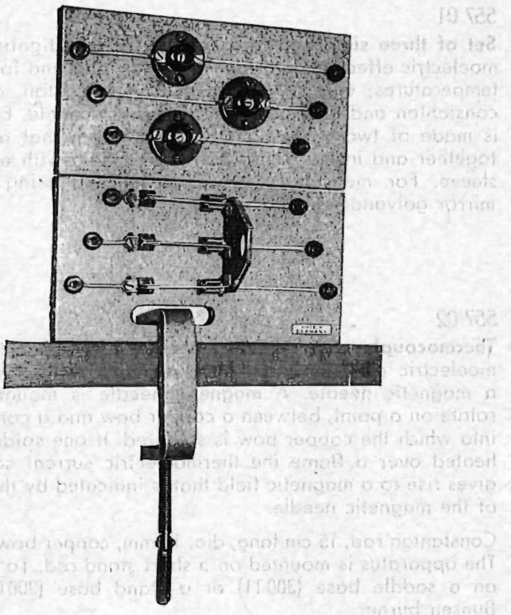
Electric driving motor, for 220 V, 70 W, for driving the generator models at constant number of revolutions, especially when performing measurements. Also for many other purposes, especially for driving the Van de Graaff generator (541 70).

Power output up to 45 W; maximum number of revolutions 6,000 r.p.m., with two belt pulleys, diameters 35 and 60 mm, respectively, with driving belt and bench clamp.

The number of revolutions per minute can be regulated by means of a rheostat, 320 Ω (537 23) connected in series.

563 36

Electric driving motor, for 110 V, 70 W, otherwise same as for 563 35. The number of revolutions per minute can be regulated by means of a rheostat, 110 Ω (537 24).

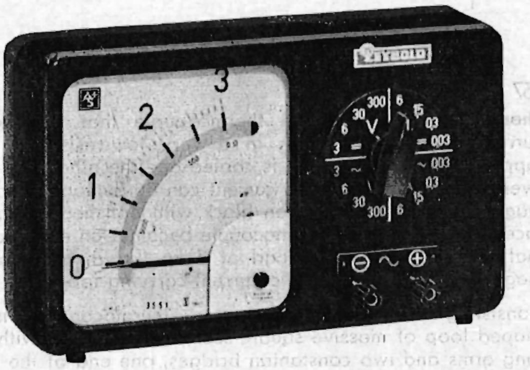


563 32

563 32

Three-pole lever switch with three E 10 lamp sockets; switch and sockets mounted on separate boards, can be used separately. They can be used together to synchronise three-phase motor models: the lamps are then connected into the supply leads of the three phases and differences between the number of revolutions of the rotor and that of the field during the acceleration process are indicated by brightness fluctuations. As soon as the rotor has attained its synchronous number of revolutions, these fluctuations will cease; the lamps are then short-circuited by means of the lever switch and the motor will continue to run synchronously on its own.

On two separate boards that can be fitted into one another, each approx. 15×8 cm² in size, with six connecting sockets each, complete with bench clamp, but without lamps. Three 24 V lamps (505 18) are required for the synchronising process.



531 55

531 55

Universal moving-coil instrument, zero point on the left. A measuring instrument of simpler design which is particularly suitable for students' practical work and can be used for almost all problems occurring there. Series and shunt resistors are provided inside the casing. The desired range is set by means of a range selector switch. The scale of the instrument contains a transparent window concentric with it, which permits the deflection to be read from the back as well, or to be demonstrated in shadow projection.

Full scale deflection: 1 mA (at 0.1 V).

Further measuring ranges:

D.C.	wider space current:	0.03; 0.3; 1.5; 6 A
	voltage:	3; 6; 30; 300 V
A.C.	wider space current:	same as for D.C.
	voltage:	same as for D.C.

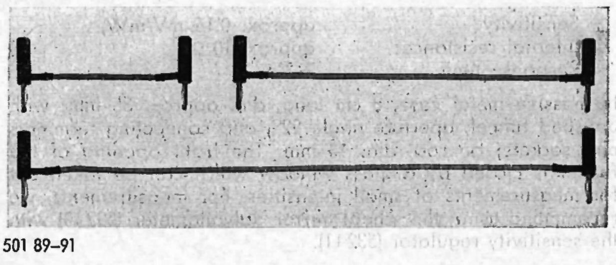
See p. 122 for further details.

531 56

531 56

Universal moving-coil instrument, zero point at the centre of the scale, otherwise same as for Cat. No. 531 55.

See p. 122 for further details.



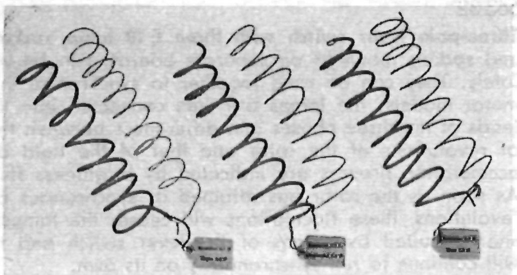
501 89–91

501 89–91

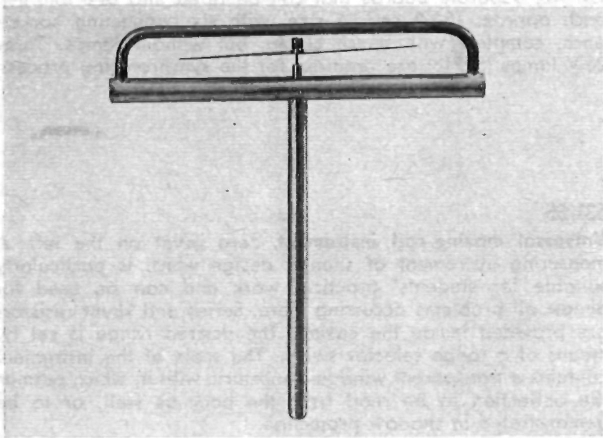
Elastic connecting leads. Unlike the types usually to be found, these leads can be stretched out up to twice their normal length, which makes for connections that do not sag. For this reason assemblies in which these leads are used appear particularly clear. When working with E.H.T. these leads are also very suitable, because they will not touch anywhere, so that sparking does not occur.

The leads contain a copper conductor that is woven tube-like about an elastic core. The outer cover consists of a hard-wearing white perlon insulation. Both ends are well insulated and connected to 4 mm plugs. The leads can be loaded up to approx. 6 A.

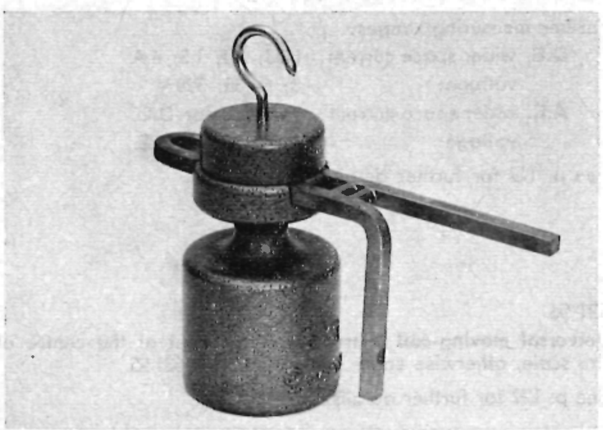
Cat. No.	Normal length	Max. length
501 89	10 cm	20 cm
501 90	25 cm	50 cm
501 91	40 cm	80 cm



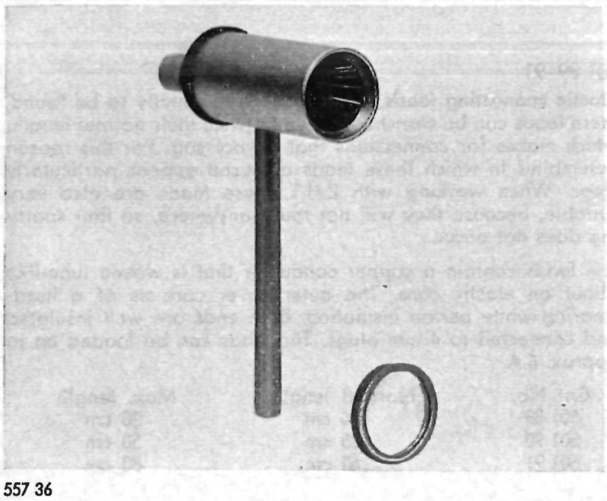
557 01



557 02



557 11



557 36

557 01

Set of three simple thermocouples, for investigating the thermoelectric effect with various thermocouples and for measuring temperatures; consisting of one iron-constantan, one copper-constantan and one nichrome-constantan couple. Each element is made of two wires about 1 m in length that are soldered together and insulated for half their length with an insulating sleeve. For measurements we recommend using the school mirror galvanometer (532 10).

557 02

Thermocouple with magnetic needle, for demonstrating thermoelectric currents and their directions by their action upon a magnetic needle. A magnetic needle is mounted, free to rotate on a point, between a copper bow and a constantan rod into which the copper bow is soldered. If one soldered joint is heated over a flame the thermoelectric current so generated gives rise to a magnetic field that is indicated by the deflection of the magnetic needle.

Constantan rod, 15 cm long, dia. 10 mm, copper bow, dia. 5 mm. The apparatus is mounted on a short stand rod. To be mounted on a saddle base (300 11) or a stand base (300 02); without Bunsen burner.

557 11

Thermoelectric magnet; a thermocouple that will produce currents of approx. 100 A in a very low-resistance circuit (approx. 10^{-4} Ω) if one end is cooled and the other one heated over a Bunsen burner. This current can be demonstrated by its magnetic effects: a soft-iron block with polished contact surfaces surrounding the thermocouple becomes an electromagnet that will easily carry a load of 5 kp (kg wt) although it is magnetised by only a single current-carrying loop.

Consisting of: Copper-constantan thermocouple; hairpin-shaped loop of massive square-section copper bar with 10 cm long arms and two constantan bridges, one end of the copper loop being continued horizontally and the other one bent downwards.

Soft-iron cylinder with polished upper face and recesses for the copper loop, permanently fixed to a 5 kg weight; soft-iron yoke with hook, polished, for completing the magnetic circuit; overall height approx. 22 cm.

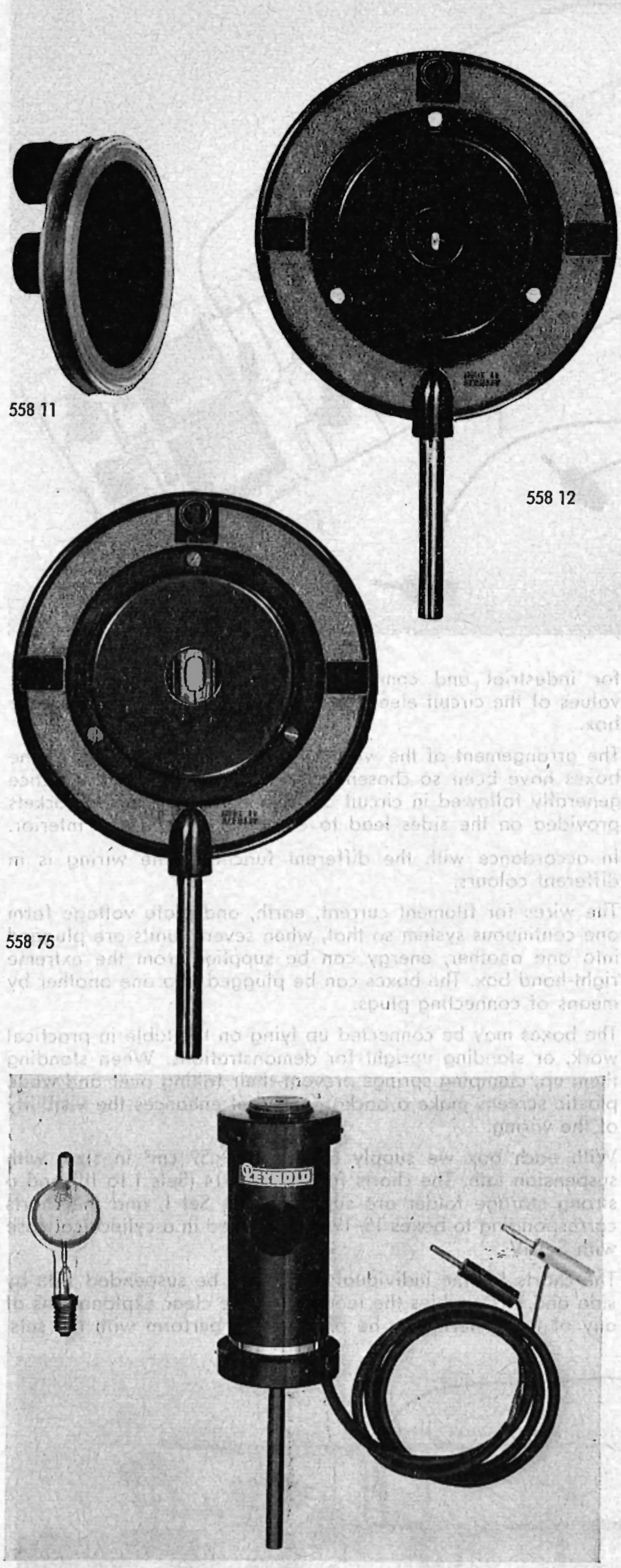
557 36

Moll's thermopile, sensitive instrument for radiation measurements, e.g. thermal radiation emitted by the black-body accessory for the electric oven (389 43) or Leslie's cube (389 26), and the energy distribution in a spectrum, or for exploring diffraction patterns.

On a surface of 10 mm diameter, the thermopile contains a series connection of 16 constantan-manganin thermocouples that are silver-soldered and blackened in front;

Sensitivity:	approx. 0.16 mV/mW,
Internal resistance:	approx. 10 Ω
Response time:	2–3 s.

In massive metal case, 8 cm long, dia. approx. 35 mm; with polished funnel, aperture angle 22°, and connecting terminals and sockets; on rod, dia. 10 mm. The front opening of the funnel is closed by a glass window which can be taken out for measurements of small intensities. For measurements, we recommend using the school mirror galvanometer (532 10) with the sensitivity regulator (532 11).



558 77

Photocell for determining Planck's constant h*)

558 78

Housing for the photocell for determining Planck's constant h*)

558 11

Selenium photocell, photovoltaic photocell that gives rise to an e.m.f. when irradiated with light. It can be used for the following experiments: transformation of light energy into electrical energy, discussion of the photovoltaic effect, photometrical measurements (exposure meter), light barrier arrangements for timing and counting, etc.

The cell is not very susceptible to damage mechanically and electrically. With small external resistances (up to approx. 10 Ω) the photocurrent is, to a good approximation, proportional to the intensity of illumination. The dependence of the sensitivity upon frequency corresponds approximately to that of the human eye, but the cell responds to ultraviolet light as well.

Open-circuit voltage: approx. 200 mV at 100 lux; internal resistance: 500 Ω, saturation value of the voltage: 500 to 600 mV, surface area: 10 cm², covered with protective varnish; in plastic case, dia. approx. 50 mm, with two terminals with sockets for making electric connections.

Recommended accessories:

School mirror galvanometer	532 10
Demonstration multirange meter	531 86
Holder with spring clips	460 22

558 12

Photodiode in case, semiconductor diode whose resistance changes when it is exposed to light, or which can be used as a photovoltaic cell. The photodiode can be used for photometric measurements, e.g. for measuring interference patterns. Such measurements can be performed particularly well with the amplifier (580 00). The demonstration scaler (559 62) provides two important applications: in light barriers for measuring the velocities of fast-moving objects and for changing light signals to electric pulses, e.g. when measuring frequencies by stroboscopic or rotating-mirror devices.

Characteristic data:

Germanium diode, sensitivity:	approx. 30 mA/lm or 3×10^{-5} mA/lx;
Size of sensitive area:	1 mm²
Wavelength for maximum sensitivity:	1.5×10^{-6} mm
Dark current:	3.5×10^{-6} A
Infrared limit:	1.9×10^{-6} mm.

Limiting characteristics:

Maximum operating voltage:	100 V,
Maximum power dissipation:	50 mV
Maximum casing temperature:	50° C

Photodiode in case, on stand rod, dia. 10 mm, with three 4 mm connecting sockets on the rear marked "plus", "minus" and "Erde" (earth).

We recommend using the photodiode with the demonstration scaler (559 62) or with the low-frequency amplifier (580 00).

558 75

Photocell in frame, alkali photocell for demonstrating the photoelectric effect, for photometric measurements and for converting light signals into electrical signals, e.g. in combination with an oscilloscope or an amplifier. When in operation, the cell must be connected in series with a protective resistance of 0.1–1 MΩ (536 25 or 536 20).

Characteristic data:

Maximum operating voltage:	150 V.
Sensitivity:	100 μA/lm
Useful sensitive area:	approx. 9 mm²

Photocell in frame, on shaft, dia. 10 mm, with three 4 mm connecting sockets on the rear, which are marked "plus", "minus", and "Erde".

Ancillary apparatus useful in the above-mentioned applications:

School mirror galvanometer	532 10
Amplifier	580 00
Demonstration multirange meter	531 86
Measuring amplifier	532 01
School cathode ray oscilloscope	575 15

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*) Details will be found in the section "Atomic Physics", p. 176

Electronics Demonstration Sets

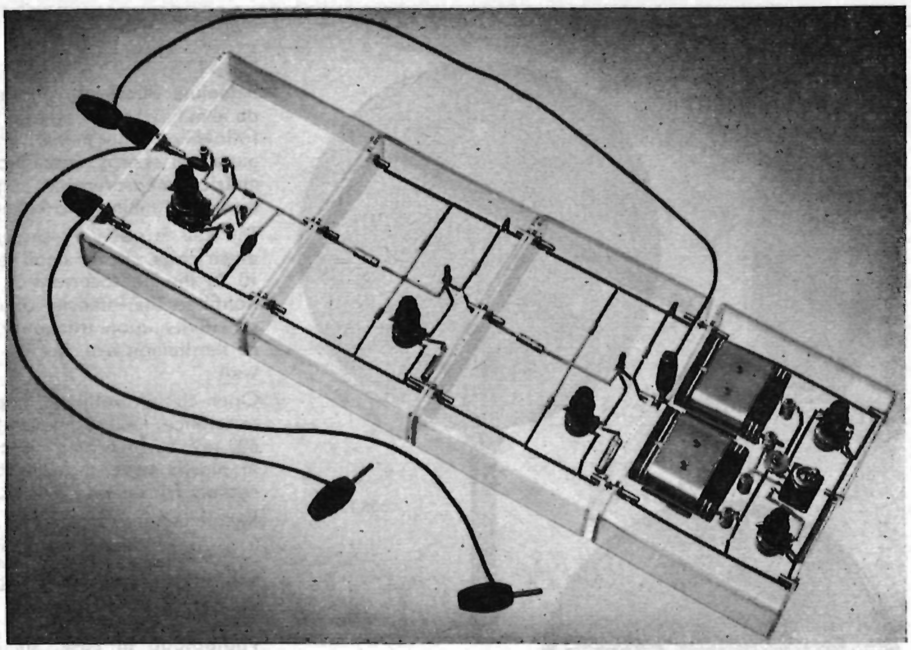

Fig. 96
Assembly of an RC-oscillator for frequencies ranging from 2 to 7.5 kc/s, from boxes (from left to right) 18, 17, 17, and 15 of Electronics Demonstration Set IV.

PH 2076

The electronics demonstration sets can be used to perform basic experiments as an introduction to the field of electronics. The units are grouped in one principal set I and two supplementary sets II and III. The fields covered include the functions of thermionic tubes (valves), their characteristic properties and basic circuits, the generation and amplification of electrical oscillations, and the foundations of radio reception.

The Electronics Demonstration Set IV is devoted to the study of semiconductor elements. The characteristic properties of transistors, semiconductor diodes, Zener diodes, NTC- and VDR-resistors can be determined and measured. (NTC = negative temperature coefficient, VDR = voltage dependent resistance). These observations can be made both on the semiconductor element itself and on the element connected up in one of its basic circuits. Moreover, the generation of electrical oscillations and their amplification can be treated.

The electronics demonstration sets consist of equally dimensioned boxes that can be connected together according to the same diagrammatic plan. Each box has already been provided with the essential circuit elements, depending upon the function it is to perform. The boxes are made of transparent plastic material, so that the circuit elements and the wiring are clearly visible. All units are equipped with the types of thermionic tubes (valves), capacitors, resistors, etc., that are usually used for industrial and commercial purposes. The characteristic values of the circuit elements can be read from the top of the box.

The arrangement of the wiring and the circuit elements in the boxes have been so chosen as to correspond to the practice generally followed in circuit diagrams. The connecting sockets provided on the sides lead to coloured leads in the interior.

In accordance with the different functions, the wiring is in different colours.

The wires for filament current, earth, and plate voltage form one continuous system so that, when several units are plugged into one another, energy can be supplied from the extreme right-hand box. The boxes can be plugged into one another by means of connecting plugs.

The boxes may be connected up lying on the table in practical work, or standing upright for demonstrations. When standing them up, clamping springs prevent their falling over and white plastic screens make a background that enhances the visibility of the wiring.

With each box we supply a chart, 35×59 cm² in size, with suspension lath. The charts for boxes 1–14 (Sets I to III) and a strong storage folder are supplied with Set I, and the charts corresponding to boxes 15–19 are supplied in a cylindrical case with Set IV.

The charts for the individual boxes can be suspended side by side and this enables the teacher to give clear explanations of any of the experiments he proposes to perform with the sets.

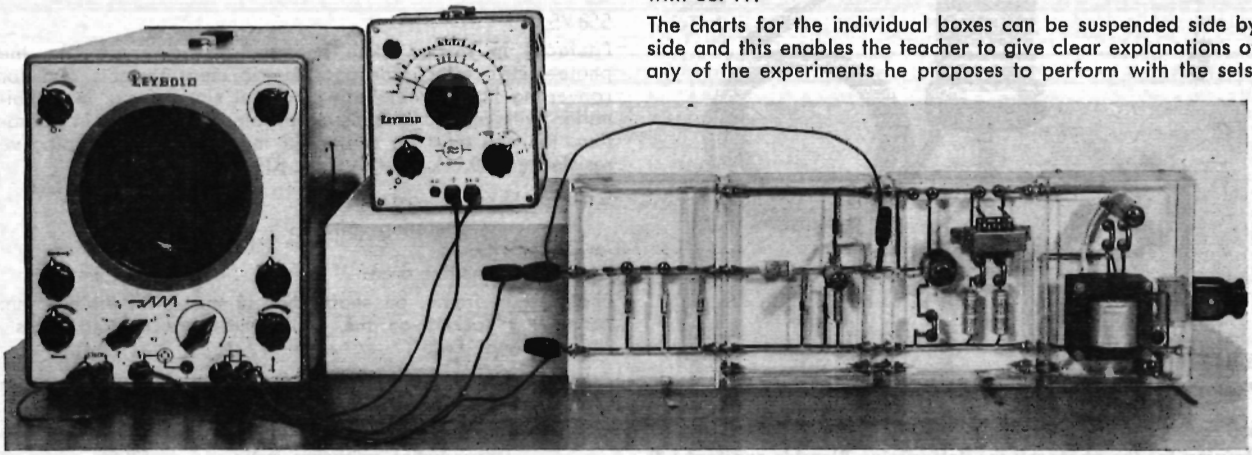

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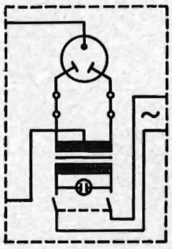
Fig. 97 Arrangement for observing frequency and phase, assembled from boxes (from right to left) 1, 2, 6, and 12 of the Electronics Demonstration Sets I–III, RC-oscillator (58700), and the school cathode ray oscilloscope (57515).

Survey of Electronics Demonstration Sets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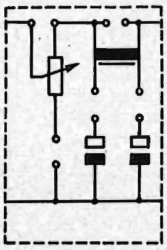
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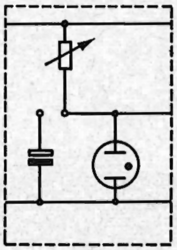
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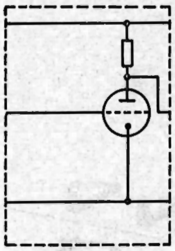
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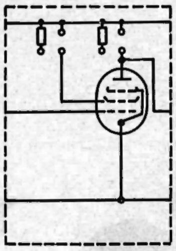
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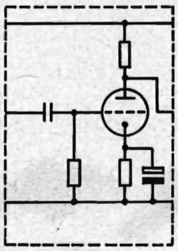
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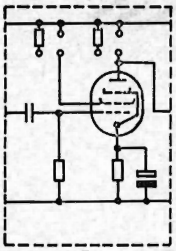
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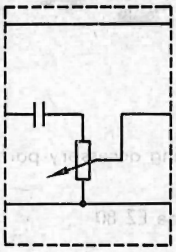
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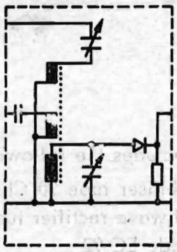
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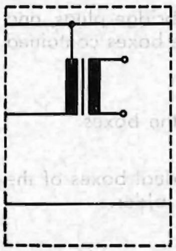
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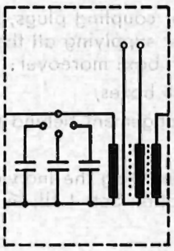
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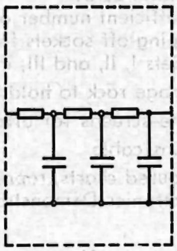
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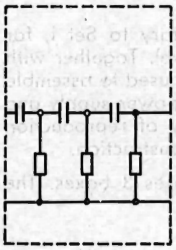
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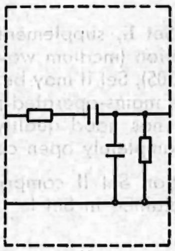
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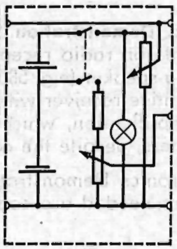
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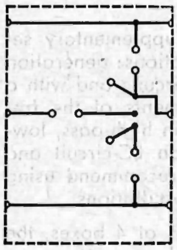
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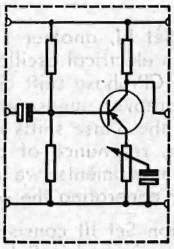
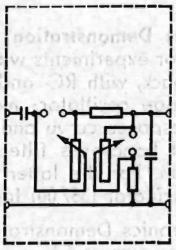

17 (2x)


18

Electronics Demonstration Set I (586 56)

No.	Name:	Use or experiments	Tube	Technical data
1	Mains transformer	Voltage supply for D.C. and A.C. voltages, Characteristic curve of a diode, Rectification	EZ 80	Transformer: primary tappings for 110, 220, 240 V, secondary tappings for 6.3 V/1.5 A, 2×270 V/60 mA
2	Smoothing filter	Smoothing of the rectified A.C. Study of the functions of the different components of the filter net-work		Potential divider, 10 W, for varying the D.C. voltage between 0 and 270 V
3	Neon tube circuit	Properties of a glow discharge tube, characteristic curves, use as voltage regulator (VR tube).	90 C1	Voltage for stabilisation: 90 V; Supply voltage: max. 400 V, for currents up to a maximum of 40 mA
4	Triode	Properties and characteristics of a triode, amplification of small D.C. voltages applied at the grid.	EC 92	Supply voltage: max. 300 V; anode dissipation: max. 2.5 W
5	Pentode	Recording the static and dynamic characteristics of a pentode	EL 84	Max. supply voltage: 300 V, maximum anode dissipation: 12 W
6	Audio-frequency amplifier	Amplification of A.C. voltages of approx. 30 c/s up to 300 kc/s	EC 92	Amplification factor: approx. 40
7	Output amplifier	Amplification of A.C. voltage of between 30 c/s and 300 kc/s for connection to the matching transformer, box No. 10	EL 84	Amplification factor: approx. 35

Electronics Demonstration Set II (586 57)

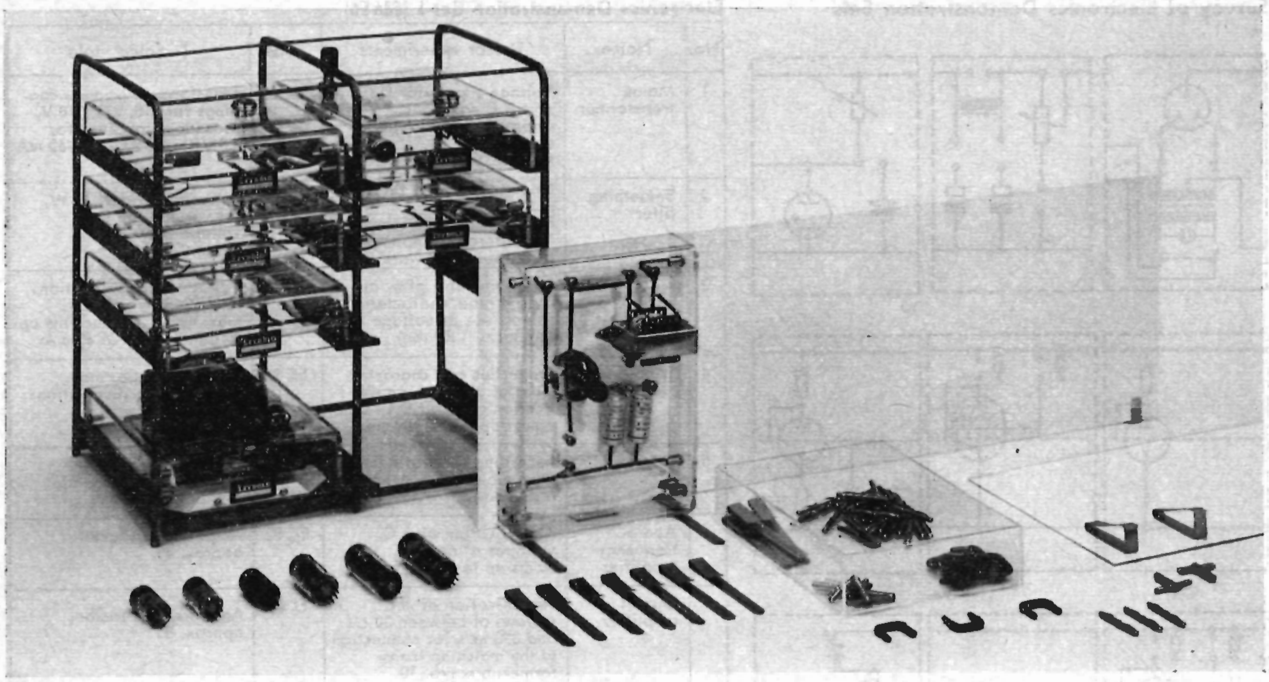
8	Potential divider	Reduction and control of A.C. voltage amplitudes in amplifier and oscillator circuits.		1 MΩ, 0.25 W
9	RF resonant circuit with rectifier	Reception of electromagnetic waves in the frequency range between 600 kc/s and 1.3 Mc/s.		Germanium diode OA 81, rotary variable capacitors, and ferrite rod with 3 windings
10	Matching transformer	Matching a low-impedance speaker to boxes 6 and 7.		Attenuation ratio 40:1

Electronics Demonstration Set III (586 58)

11	Meissner circuit	Generation of electric oscillations by means of feed-back, modulation		Ferrite core with 3 windings
12	RC-circuit	Generation of electric oscillations, measurements on a low-pass filter		Phase shift: 180° at $\nu = 3.9$ kc/s
13	CR-circuit	Generation of electric oscillations, measurements on a high-pass filter		Phase shift: 180° at $\nu = 650$ c/s
14	Wien bridge circuit	Generation of electric oscillations, measurements on a band-pass filter		Phase shift: 0° at $\nu = 1.6$ kc/s

Electronics Demonstration Set IV (586 59)

15	Battery-operated voltage supply	Voltage supply, variable: 0-9 V and 0- approx. 0.5 V		With indicator lamp; two 4.5 V batteries are required.
16	Semi-conductor test box	Recording the characteristic curves of all semiconductor elements	S 33; SZ 6; OC 71; NTC-resistor VDR-resistor	Connections for base, emitter and collector and for the supply voltage are provided; with sockets for measuring the current
17 (2 x)	Transistor amplifier	Amplification in the frequency range from 30 c/s to 10 kc/s; generation of electric oscillations, for use with box 18	OC 71	Maximum supply voltage: 10 V
18	Variable Wien bridge circuit	Generation of oscillations, for use with 2 × box 17		Frequency: approx. 2 to 8 kc/s



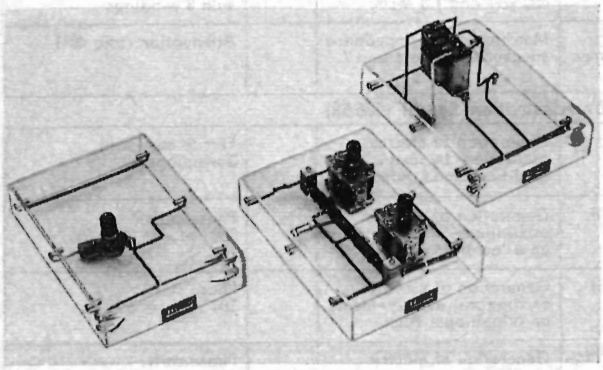
586 56 (boxes 1–7, with accessories)

586 56

Electronics Demonstration Set I, for studying the most important types of valves and for assembling simple electronic circuits such as filter circuits, stabiliser circuits, mains rectification circuits, amplifier circuits, etc. This set includes the power for sets I, II, and III and consists of 7 boxes.

The set includes the following accessory parts:

1 Stabiliser tube 90 Cl
1 Full-wave rectifier tube EZ 80
1 Triode EC 92
1 Pentode EL 84
A sufficient number of coupling plugs, bridge plugs, and tapping-off sockets for supplying all the boxes contained in Sets I, II, and III, in box; moreover:
1 Storage rack to hold 8 boxes,
2 white screens for arrangement behind the boxes
1 Mains cable
14 coloured charts, representing the individual boxes of the Electronics Demonstration Sets I–III, in folder.

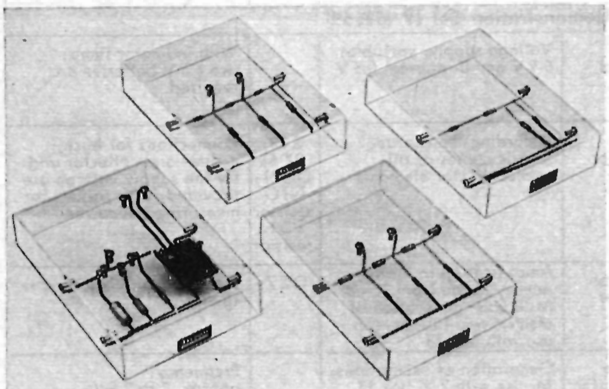


586 57 (boxes 8–10)

586 57

Electronics Demonstration Set II, supplementary to Set I, for experiments on radio reception (medium wave). Together with Set I and a speaker (e.g. 580 05), Set II may be used to assemble a regenerative receiver with mains-operated power supply and power amplification, which has good quality of reproduction and loudness, despite the completely open construction.

The Electronics Demonstration Set II comprises 3 boxes. The accessories needed are contained in Set I.

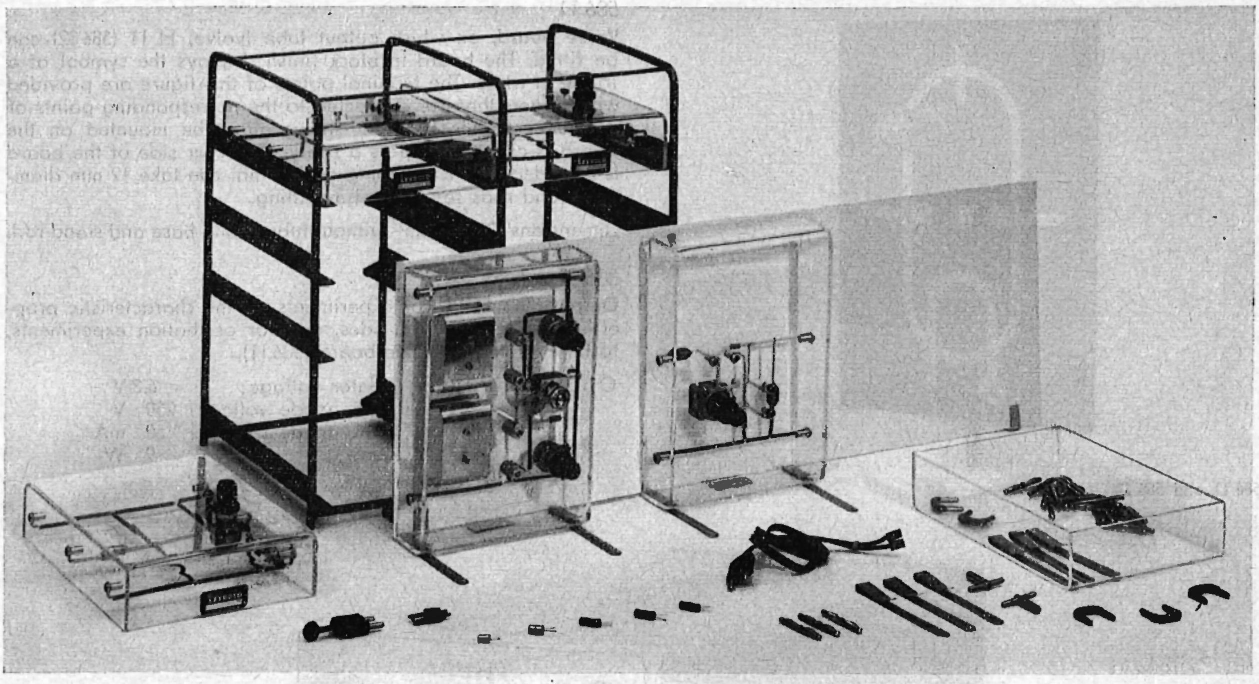


586 58 (boxes 11–14)

586 58

Electronics Demonstration Set III, another supplementary set to Set I, for experiments with electrical oscillations: generation by feed-back, with RC- and CR-phase shift circuits and with a Wien bridge oscillator; moreover, measurements of the frequency response curve and the phase shifts in high-pass, low-pass, and band-pass filters, resonance of an LC-circuit and modulation. For the latter experiments, we recommend using the RC-oscillator (587 00) for generating the oscillations.

The Electronics Demonstration Set III consists of 4 boxes, the accessories required being contained in Set I.

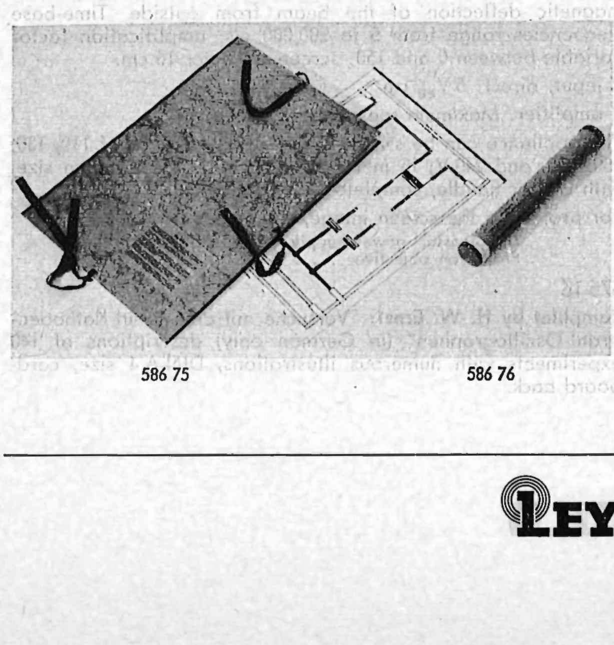


586 59 (boxes 15–18 and accessories)

586 59

Electronics Demonstration Set IV, a self-contained set for determining the most important properties of the semiconductors that are used in modern electronics. The usual elements: diode, transistor, VDR (voltage-dependent resistance)- and NTC (negative temperature coefficient)-resistor are studied with respect to their most vital properties and their applications.

586 70



586 75 586 76

The Electronics Demonstration Set IV consists of 5 boxes and contains in addition:

3 Transistors
1 Diode
1 Zener diode
1 NTC-resistor
1 VDR-resistor

In addition, it contains a sufficient quantity of coupling plugs, bridge plugs and tapping-off sockets, in a box.

Also provided: one storage rack for 8 boxes and one white screen, as well as 5 coloured charts showing the circuitry of the individual boxes contained in Electronics Demonstration Set IV, rolled up in a cylindrical case.

Two flat batteries of 4.5 V each must be obtained from an electrical shop.

586 70

Storage rack, for clear and economic storage of 8 boxes from the Electronics Demonstration Sets I to IV. One such rack is included with each of Sets I and IV. Therefore we recommend ordering such a rack for Sets II and III.

586 75

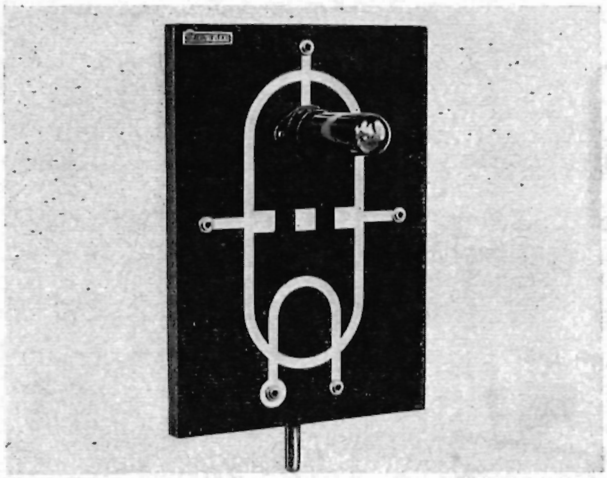
Set of 14 charts in a folder, for the Electronics Demonstration Sets I–III. The charts show the circuitry of the boxes 1 to 14 in colour, size: 35×59 cm², with suspension lath. The charts are washable and may be written upon; one set of charts is supplied with the Electronics Demonstration Set I (586 56).

586 76

Set of 5 charts in a cylindrical case, for the Electronics Demonstration Set IV. Same finish as for Cat. No. 586 75, but with charts representing boxes 15 to 18. One set of these charts is supplied with Electronics Demonstration Set IV.

A book of experiments supplied free of charge with the sets gives details about how to experiment with the boxes.

Apparatus for further introductory experiments on the mechanism of electric conduction in solids (metals and semi-conductors), please see appendix, p. 208.



586 11 and 586 32

586 11

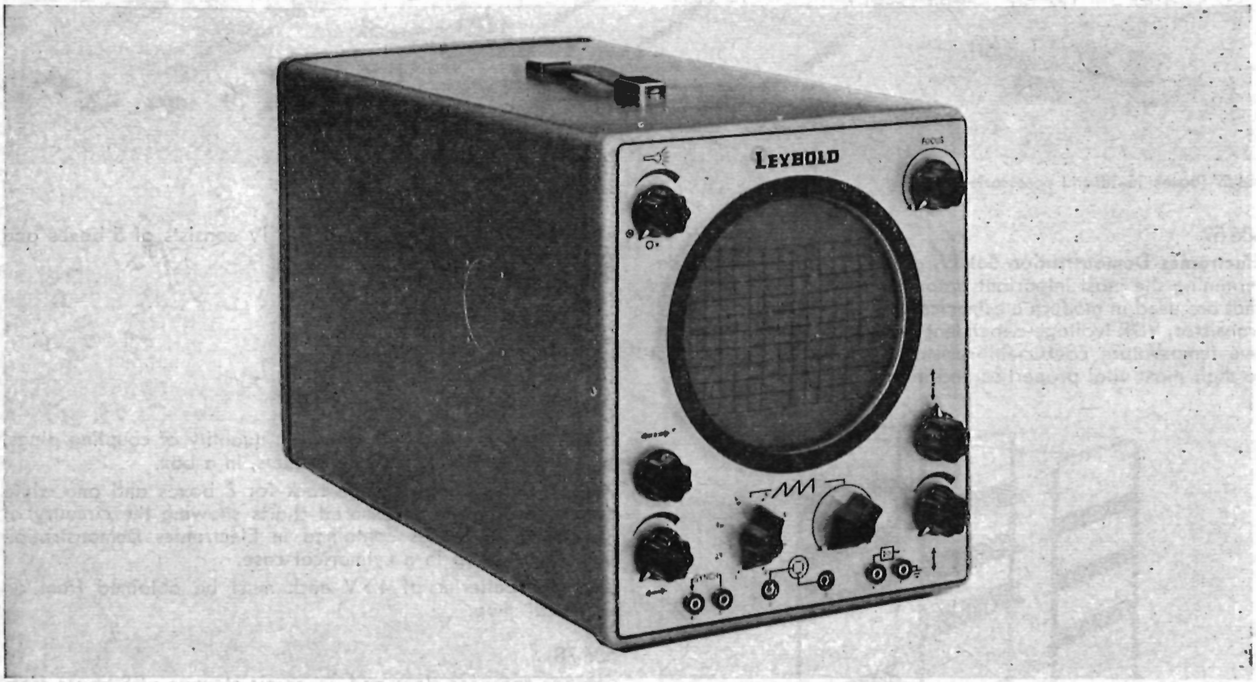
Valve board, on which output tube (valve) EL 11 (586 32) can be fitted. The board in black finish displays the symbol of a triode in white. The terminal points of this figure are provided with sockets that are connected to the corresponding points of the tube. As the diagram shows, the tube mounted on the board is connected up as a triode. The rear side of the board is provided with a clamping device that can take 12 mm diameter stand rods for vertical mounting.

Dimensions: 21 × 30 cm^2, without tube, stand base and stand rod.

586 32

Output tube EL 11, for experiments on the characteristic properties of diodes and triodes, and for oscillation experiments, to be mounted on valve board (586 11).

Operating data: Heater voltage: 6.3 V
Max. anode voltage: 250 V
Max. anode current: 50 mA
Plate dissipation: 9 W



575 15

575 15

School cathode ray oscilloscope, indispensable for measurements and demonstrations in the fields of electricity, electrical oscillations, and acoustics. The apparatus here described has been specially designed for the requirements of teaching, unlike most other oscilloscopes. It has a large screen, the image is sufficiently brillant, even if the room is not darkened; for projection purposes, the brilliance can be increased by post-acceleration, the operating knobs, switches and sockets are clearly arranged and therefore easy to operate.

All functional elements required for physics teaching purposes are provided within an easily handled case, thus avoiding additional preparation work.

Special care has been devoted to the design of the time-base unit for horizontal time-proportional deflection. The saw-tooth voltage is excellently linear and can be synchronised either by the vertical deflecting pulses or by external signals. If desired, the time-base voltage can be switched off or – e.g. for the purpose of synchronous excitation of an oscillatory circuit – tapped off and supplied to an external circuit.

The electron beam can be post-accelerated using a pair of sockets at the rear of the casing, or its brightness can be controlled by means of a controlling voltage. A hole covered with aluminium foil on either side of the casing permits magnetic deflection of the beam from outside. Time-base frequencies range from 5 to 200,000 c/s; amplification factor variable between 0 and 150; screen diameter 16 cm.

Y-input, direct: 5 V_{eff}/cm

Y-amplifier: Maximum sensitivity 25 mV_{eff}/cm

The appliance can be switched for mains voltages of 110, 130, 150, 220, and 240 V; in metal case, 26.5×31×52.5 cm^3 in size, with carrier handle, complete with mains cable.

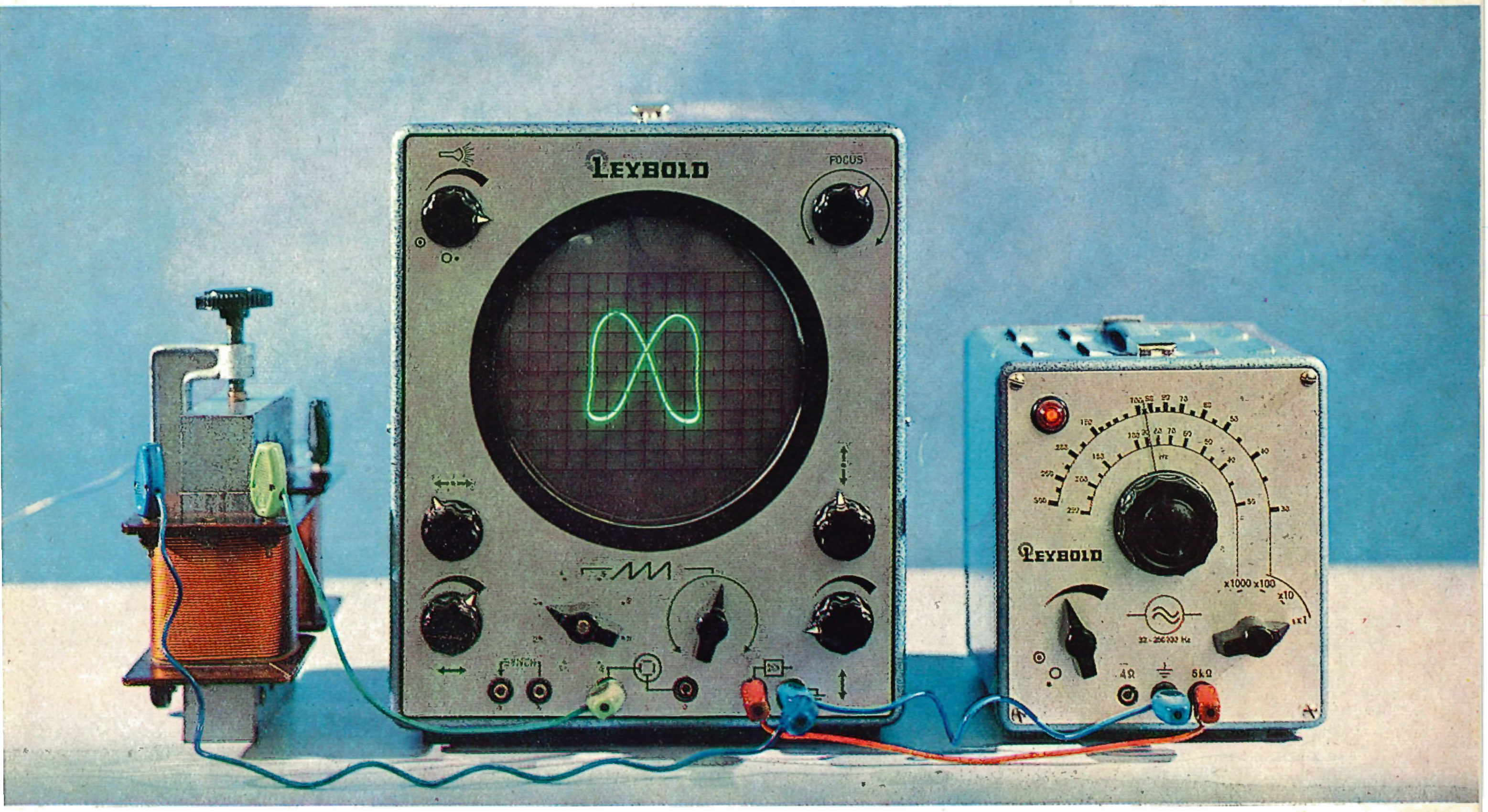
For projecting the screen image, we recommend using:

High-tension power supply	522 37
Projection objective	460 13

575 16

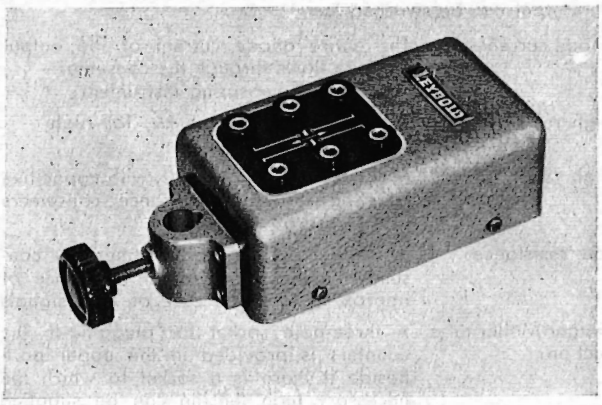
Pamphlet by H. W. Ernst: "Versuche mit dem Schul-Kathodenstrahl-Oszillographen" (in German only) descriptions of 140 experiments with numerous illustrations, DIN A 4 size, cardboard back.

LEYBOLD


LEYBOLD
FOCUS
SYNCH
LEYBOLD
x1000 x100
x10
x1
4Ω
5kΩ

Lissajous figures are formed on the oscilloscope screen by the superposition of two sinusoidal alternating voltages, of which one, of mains frequency, is derived from the demountable demonstration transformer and the other, of variable frequency, from the RC-oscillator.

PLATE IX



504 98

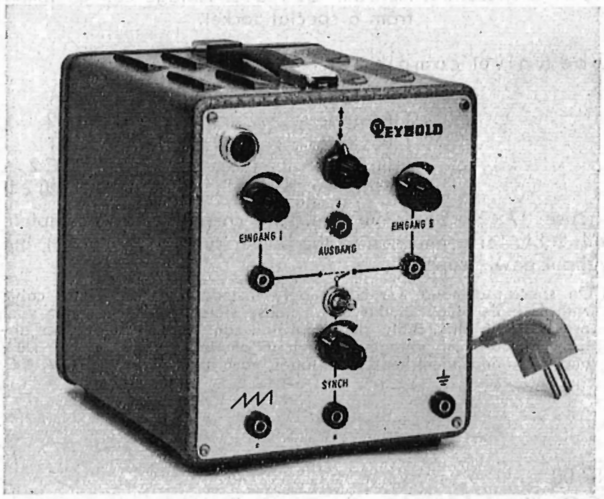
504 98

Rotary two-way switch, for regularly recurring switching operations; in particular, suitable for use with oscilloscopes as when investigating the voltage characteristic of capacitors or coils or the current-voltage characteristics of A.C. circuits.

The unit contains two identical, but electrically separated, rotary reversing switches. Therefore each of the two switches can be used to complete two circuits having one pole in common alternately during successive half revolutions, so that four circuits in all can be connected simultaneously. In this manner almost all the circuits of the above-mentioned kind can be established with this switch.

Contained in a metal case (approx. 12×7×5 cm^3), with clamping device for stand rods up to 12 mm diameter, protruding shaft (dia. approx. 10 mm) for mounting in the chuck of the standard electric motor (347 25/26), for frequencies of up to 500 r.p.m. With six 4 mm sockets on the front panel and printed-on switch diagram. Will take up to 125 V, 5 A when loaded resistively.

We recommend operating the switch with the standard electric motor (347 25 or 347 26).



575 18

575 18

Electronic switch, for converting the school cathode ray oscilloscope (575 15) into a double-beam cathode ray oscilloscope enabling two independent voltages to be displayed simultaneously. This is a considerable added convenience for the experimenter, especially when investigating the phase shifts between voltages and currents and charging and discharging processes in electric circuits, etc.

Technical data:

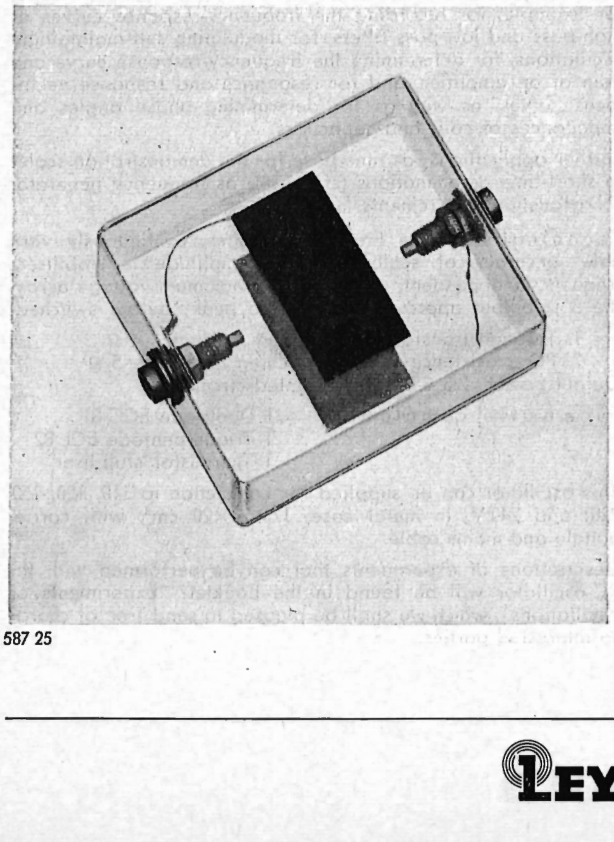
Two independent, continuously variable input amplifiers; sensitivity: 250 mV/cm per unit, amplification factor: 25.

Continuous line separation over the entire width of the oscilloscope screen.

Variable synchronisation amplifier that can be switched to either input.

Switching frequency: 5 c/s to 20 kc/s.

In case, 17×22×20 cm^3 in size, with carrier handle, complete with indicating glow-lamp and mains cable, 2 m long; can be switched for mains voltages of 110/130/150/220/240 V.



587 25

587 25

Rochelle salt crystal in case, for observing the piezoelectric and the ferroelectric effects. The voltage that occurs at the electrodes when the crystal is stressed mechanically can be indicated by means of the Wulf electroscope (546 00). When the crystal is exposed to sinusoidal mechanical loads (e.g. by holding a sounding tuning fork against it, 414 42 or 411 81), an alternating voltage will be produced, which can be demonstrated with the school cathode ray oscilloscope (575 15) or with the amplifier (580 00) with small speaker (580 05). When the crystal is connected to a source of A.C. with two capacitors in series, and to the oscilloscope, interposing a rheostat, the hysteresis loop can be shown.

Rochelle salt crystal with electrodes and two connecting sockets, in elastic, transparent case, 7×6×3 cm^3 in size, moisture-proof.

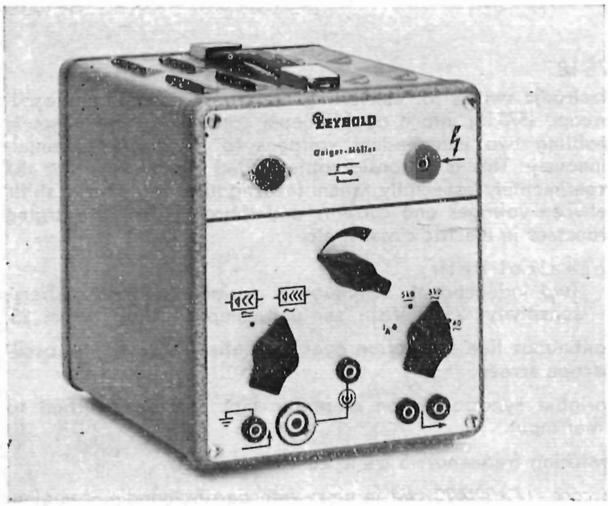
580 00

Amplifier, two- or three-stage D.C. and A.C. amplifier for use in teaching, additionally containing the necessary facilities for connecting a Geiger-Müller counter tube, and several switched differently matched output stages. Some important applications of this amplifier are: microphone and record amplification, AF-amplification in radio reception, amplification of microphone signals (from 586 27 or 586 29) during measurements in an acoustic field, amplification of counter-tube pulses for feeding a speaker, mechanical register, or milliammeter, amplification of the 100 c/s signals from the receiver for the microwave transmitter (582 30), which are then supplied to a speaker for indication; amplification of photocurrents from the photocell (558 75) or the photodiode (558 12).

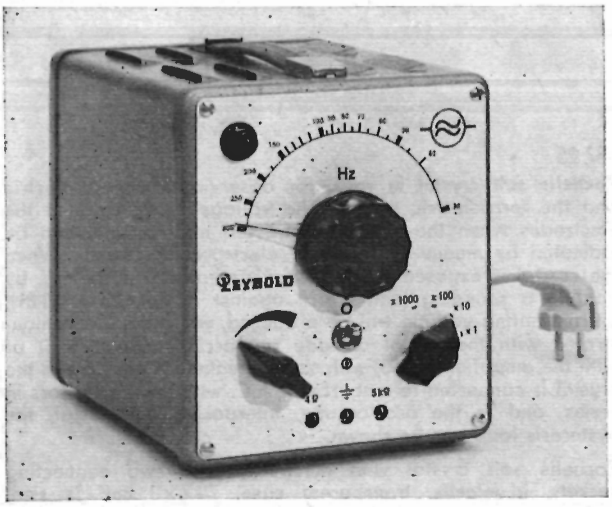
Technical data:

Power amplification, two-stage:	up to 500×
three-stage:	up to 20,000×
Total transconductance:	100 mA/V
Anode current of output tube:	26 mA

Voltage supply: The unit has no power supply unit. It is best operated from power supply (522 35/33) which is provided with a multiple socket for this purpose.



580 00



587 00

The output can be switched to:

Anode current:	The entire anode current of the output pentode flows through the consumer – generally a measuring instrument;
High resistance:	Matching resistance: 5 kΩ, for high-resistance consumers;
High resistance:	Matching resistance: 5 kΩ, with capacitive coupling, for high-resistance consumers in the case of A.C. signals;
Low resistance:	matching through a transformer, for consumers having an internal resistance of approx. 4 Ω, in the case of A.C. signals
Geiger-Müller tube section:	A three-pole socket for plugging-in the counters is provided in the upper part. Beside it there is a socket to which the necessary high tension can be supplied from the high-tension power supply (522 37).
Photocell operation:	Approx. 100 V D.C. voltage can be taken from a special socket.

Tube (valve) complement:

1 Pentode	EF 41
1 Pentode	EF 42
1 Pentode	EL 41
1 Stabiliser tube	150 C 2
1 Stabiliser tube	STV 100/60 Z II

In case, 17×22×20 cm³ in size, with carrier handle, complete with cable for connection to the power supply (522 35/33*), but without power supply.

*) On special demand, we can supply instead a multiple-core cable with 6 single plugs (in this case, please state No. 310 03 106 on your order). With this cable the amplifier can be operated from any desired source of voltage yielding an anode D.C. of approx. 300 V and two independent heating voltages, each of 6.3 V, approx. 1 A A.C.

587 00

RC-Oscillator, for generating sinusoidal alternating voltages in the frequency range from 30 c/s up to 300 kc/s. Can be used for many measurements, especially in combination with the electronics demonstration sets and a cathode ray oscilloscope, for example, for recording the frequency-response curves of high-pass and low-pass filters, for modulating self-maintaining oscillations, for determining the frequency-response curve and gain of an amplifier, and for resonance and response vector locus curves, as well as for determining phase angles and impedances of coils and capacitors.

Further applications: as time-base for the demonstration scaler in short-time deteminations (cf. p. 16); as frequency generator for acoustic measurements (see p. 17).

Technical data: 4 Frequency ranges, continuously variable, accuracy of scale 3%. The amplitude is stabilised, frequency-independent, and variable. Maximum voltage across the 5 Ω output approx. 75 V peak to peak; output switched:

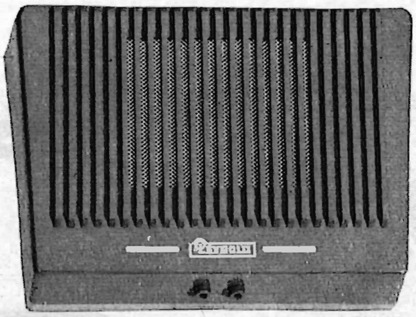
1. Through transformer, matching resistance 4 Ω
2. Pure resistance output, matching resistance 5 Ω

Output power: 2.5–3 W. With printed circuit.

Tube (valve) complement: 1 Duotriode ECC 81
1 Triode-pentode ECL 82
1 Thermistor stabiliser

This oscillator can be supplied for connection to 110, 130, 150, 220, and 240 V. In metal case, 17×22×20 cm³, with carrier handle and mains cable.

Descriptions of experiments that can be performed with the RC-oscillator will be found in the booklet: "Experiments on oscillations", which we shall be pleased to send free of charge to interested parties.

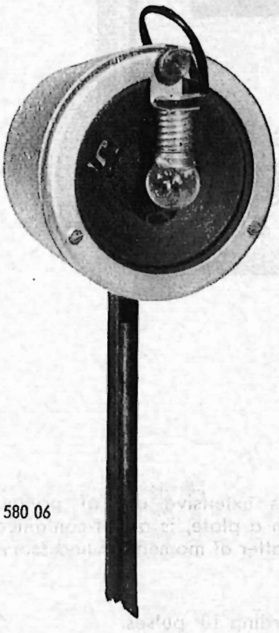


580 05

580 05

Speaker. Low-impedance, permanent-magnet system with oval membrane; for connection to A.C. generators of small internal resistance and a maximum output power of 4 W, e.g. to the output transformers of the amplifier (580 00) or of box 10 of the Electronics Demonstration Set II (586 57).

In plastic case with connecting sockets; dimensions: approx. 24×17 cm², impedance at 100 c/s: approx. 5 Ω; frequency range: 100 to 7,000 c/s; resonance peak: near 1,400 c/s; output: 3–4 W.



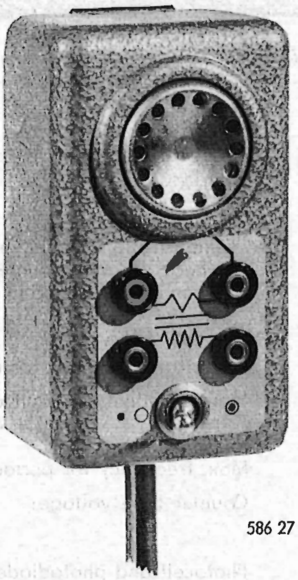
580 06

580 06

Small speaker, for electroacoustic experiments in the frequency range between 50 and 15,000 c/s. Electromagnet system with an impedance of 4 Ω, matching the low-resistance output of the RC-oscillator, power dissipation approx. 1 W.

In case, dia. approx. 70 mm, on shaft, dia. 10 mm, with 4 mm sockets.

An additional convenience:
For easy, time-saving adjustment in front of the concave mirror (389 24) by optical means, a small lamp is provided in front of the speaker, which is fed from 6 V and facilitates finding the focus by the observation of the reflected beam of light.

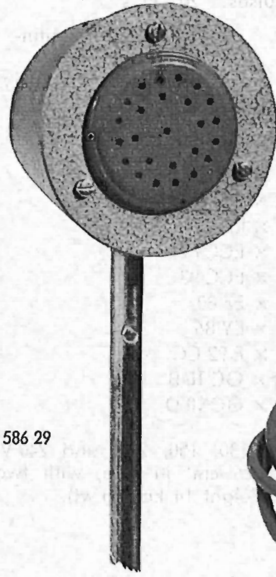


586 27

586 27

Carbon microphone, frequency range: 50 to 5,000 c/s; for the reception of sound waves and for speech and music. The microphone can also be used for the measurement of the velocity of sound in air and other gases (cf. Fig. 41, p. 75).

Response: approx. 25 mV/μbar without transformer at the direct output; matching impedance: approx. 200 Ω without transformer or approx. 100 kΩ with output transformer, transformer ratio 1:4.4. In case, approx. 13×7×5 cm³ in size, on rod, dia. approx. 10 mm, for vertical mounting and with rubber feet at the rear for horizontal operation, complete with 2 dry batteries, each of 1.5 V (Pertrix 235 or similar), working life per set of batteries approx. 25 hours. The front plate of the casing is provided with one pair of sockets for a low matching resistance and one pair of sockets for a high matching impedance, and an on-off switch. A small lamp on the front indicates that the microphone is ready for operation on being switched on.



586 29

586 29

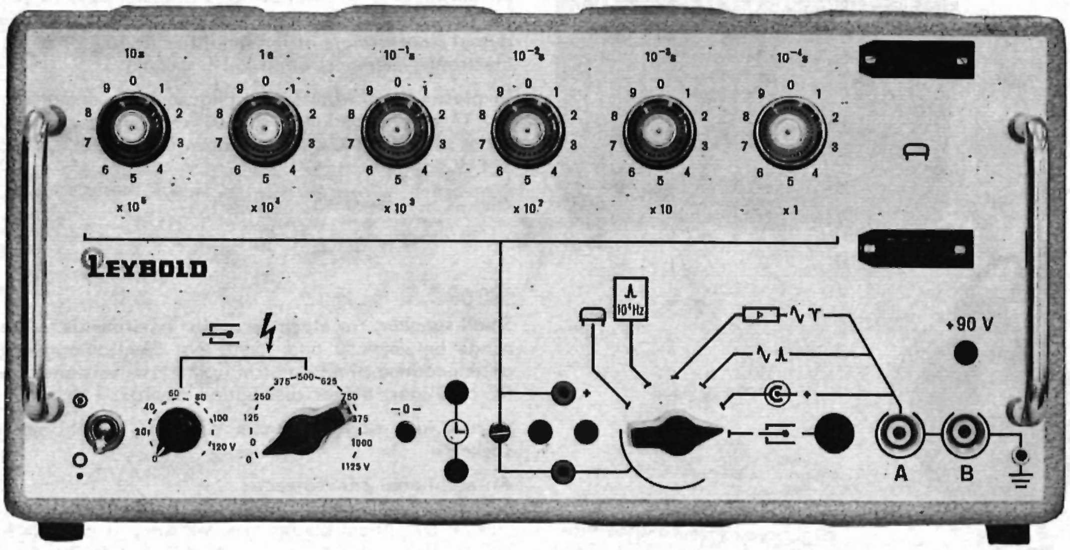
Crystal microphone, high impedance, frequency range: 50 c/s to 15 kc/s; particularly suitable for experiments with the directional sound receiver (see Fig. 38, p. 75) and for receiving speech and music; resonance peaks do not occur below 5 kc/s. Response: approx. 5.5 mV/μbar.

In conical case, max. dia. 70 mm, on rod, dia. 10 mm. With one socket for connecting the coaxial cable (586 30) or a 4 mm plug, and one earthing socket.

586 30

586 30

Coaxial cable, 1 m long, for use as screened cable in electronic experiments. Highly insulated cable with shielding and two coaxial plugs as well as detachable 4 mm extension plugs.



559 62

559 62
Demonstration scaler. Electronic unit for scaling and recording periodic or statistically distributed pulses in two main fields of application:

a) With predetermined or measured scaling period (Scaler): This includes all nucelar physics measurements with counter tubes and the various frequency determinations of electrical signals that may be produced by microphones, photocells, photodiodes, electrical oscillators or piezoelectric crystals.

b) With known pulse frequency (Timer): By counting these pulses, the duration of a physical process can be determined; this is particularly advantageous when measuring very short intervals of time. To quote a few examples: the measurement of the velocity of sound and of its dependence upon the temperature and the kind of gas, the determination of the instantaneous velocity of a Fletcher's trolley, of falling balls or of pendulums, durations of collisions in the case of elastic collisions, initial velocities in projection experiments, etc.

The pulses are indicated by 6 electronic decatron tubes with rotating spots of light which can be read from considerable distances. The instrument is so liberally equipped with switching facilities that adapting it to the different modes of application presents no difficulties.

A function-selecting switch, connections for G-M tubes and photocells, switching sockets for starting and stopping the scaling process, connecting sockets for the electric stop-clock and control knobs for the continuously variable G-M tube voltage are clearly arranged on the front panel.

Some accessories listed on p. 165 extend the range of application. The most important one of these is a quartz-controlled frequency generator for 10 kc/s used as time-base for measuring short intervals of time. In addition, the scaler is equipped with a connection for other frequency generators that may already be available, (e.g. RC-oscillator, Cat. No. 587 00).

The demonstration scaler makes extensive use of printed circuits. Each decade, mounted on a plate, is a self-contained unit and can be exchanged in a matter of moments if necessary.

Technical data:

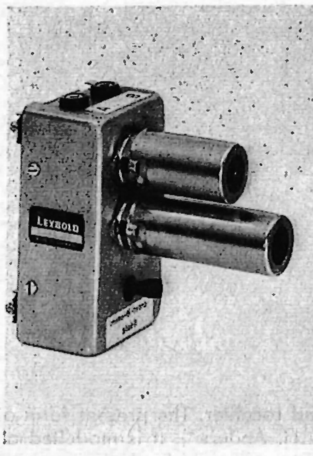
6 Electronic decades for recording 10^6 pulses.

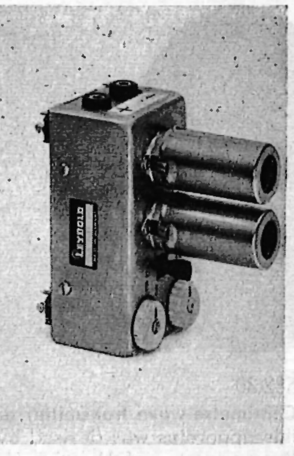
Input sensitivity without amplifier: 15 V
with amplifier: 0.2 V
Resolving time: 50 µs
Max. frequency for periodic pulses: 20 kc/s
Counter tube voltage: 0 to 1,125 V continuously variable, stabilised tc $<0.5\%$
Photocell and photodiode voltage: 90 V

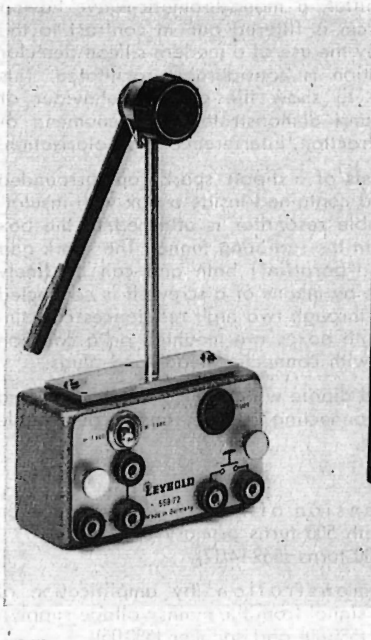
Tube (valve) complement:
1 × 90 C1
1 × 150 C2
2 × STV 500/1
1 × EC 92
1 × ECC 82
6 × ECC 83
1 × EF 80
1 × EY 86
1 × E 92 CC
5 × GC 10 B
1 × GC 10 D

Switchable for connection to 110, 130, 150, 220, and 240 V, 50–60 c/s mains; in case, 44×22×26 cm³ in size, with two carrier handles and mains cable. Weight 14 kp (kg wt).

532 01
Measuring amplifier. Amplifier with high-resistance input for measuring electric currents, voltages and charges using a low-resistance moving-coil instrument as indicating instrument. For a detailed description of the apparatus see p. 124.


559 70


559 71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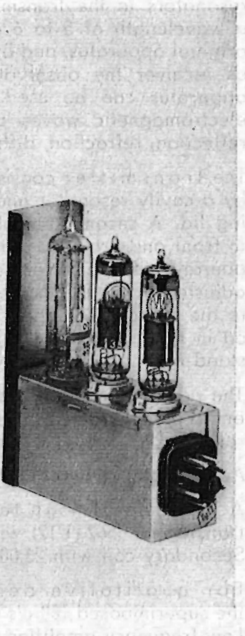
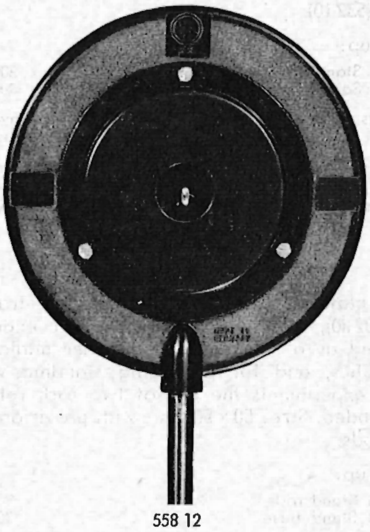

559 73


558 12

559 70

Plug-in multivibrator (flip-flop) unit to start and stop the scaler. This accessory can be used to measure short intervals of time with the demonstration scaler and enables the scaler to be started and stopped by means of electric pulses without the use of mechanically moved switching elements. This is the only means by which short times of orders below $^{1}/_{100}$ s may be measured.

The unit contains a multivibrator that can be made bi- or monostable at will. External pulses used to start or stop the scaling process are supplied to the unit via connecting sockets. However, it is also possible to supply a starting pulse to the unit by means of a push-button on the front panel of the plug-in unit, which will both start the time measurement and deliver an external electric signal; for example, when measuring the velocity of sound this pulse can be supplied to a speaker and start a sound pulse.

The unit has a built-in multiple plug. For connection it is simply plugged into the front panel of the demonstration scaler.

Tube (valve) complement: 1 × E 90 CC
1 × 6211

559 71

Plug-in ratemeter accessory for the demonstration scaler. By means of this accessory the scaler can be converted into a ratemeter indicating the mean number of pulses recorded per unit time by the scaler. The accuracy of this procedure is sufficient for many purposes, and the saving in time is considerable, as no individual measurements are required. For example, the decay of artificially radioactive isotopes, the activities of which are induced by thermal neutrons, can be watched by observing the change of position of the pointer, which indicates the mean value of the pulse rate.

By operating two switches the following measuring ranges can be selected: 0.3–3 c/s; 3–30 c/s; 30–300 c/s; 300–3,000 c/s; 3,000–30,000 c/s.

A suitable indicating instrument for the frequency is the demonstration multirange meter (531 86) or the twin moving-coil instrument (442 73/74) the movements of which should be directly connected to the plug-in unit.

Full deflection in the 300 μA range corresponds to the above p.p.s. values. Supplied without indicating instrument.

559 72

Pre-set time-switch, accessory to the large electric stop-clock (313 02/04/08). For pre-setting the time at which the running clock will establish an electric contact and the time at which it will break it. Can be used with the demonstration scaler to pre-set scaling periods, e.g. when comparing count-rates or measuring frequencies.

(More details will be found on p. 17)

559 73

Frequency generator for 10 kc/s; accessory to the demonstration scaler used as time-base when measuring time by counting periodic pulses. When fitted with this frequency generator, the demonstration scaler permits time-intervals down to $^{1}/_{10,000}$ s to be measured.

The unit contains a quartz-controlled frequency generator oscillating at a frequency of 10 kc/s and is stabilised to ±0.01% at 30° C.

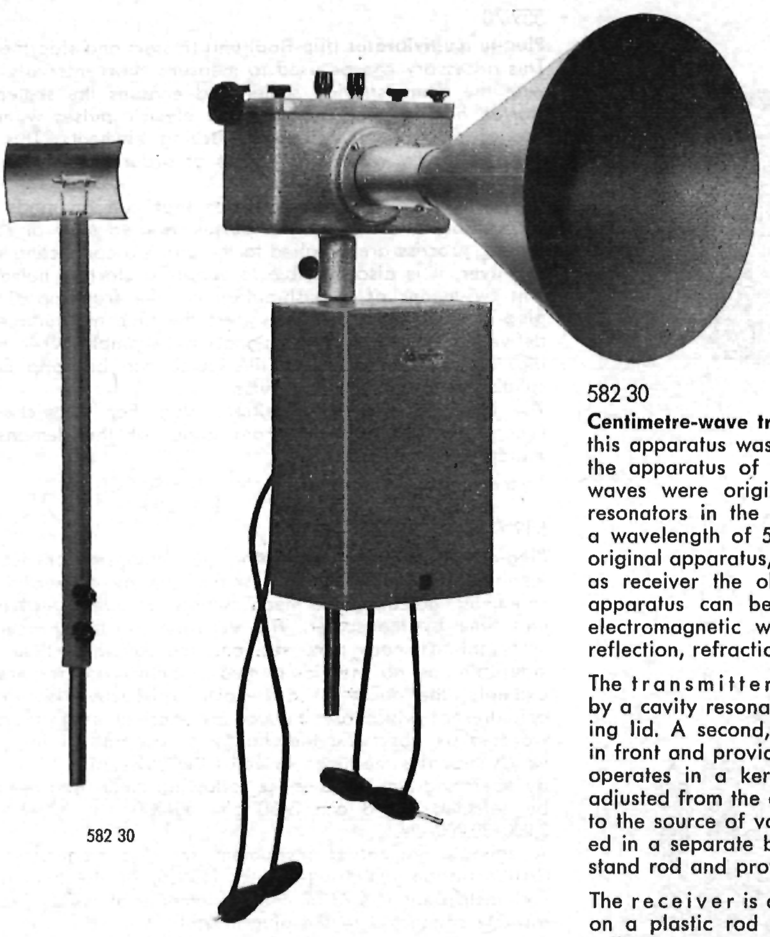
In case, approx. 26×40×48 mm^3 in size, with multiple plug for connection. The multiple socket fitting the plug is contained within the casing of the demonstration scaler so that the frequency generator can be inserted in a moment.

Tube (valve) complement: 1 × E 90 CC
1 × Q 1

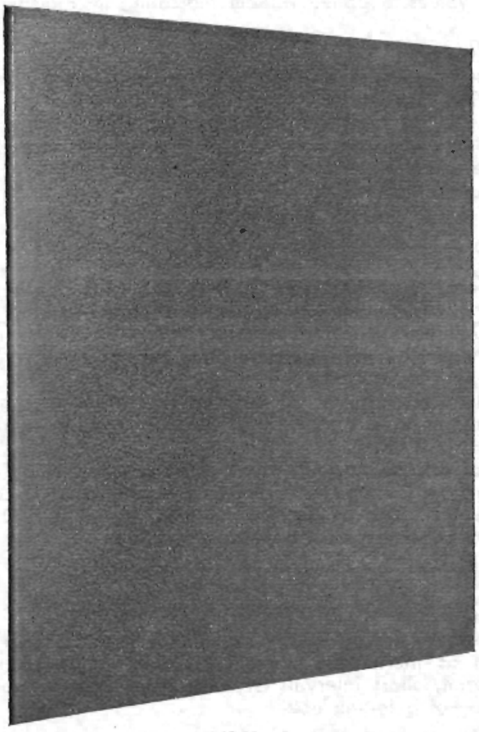
558 12

Photodiode. This device can be used to assemble light barriers acting as inertia-less switches to actuate the scaler when measuring short intervals of time, e.g. when measuring the velocity of a falling ball.

(For details see p. 155).



582 30



582 33

582 30

Centimetre-wave transmitter and receiver. The present form of this apparatus was devised by H. Anders*). It is modelled on the apparatus of Heinrich Hertz with which electromagnetic waves were originally detected. But by the use of cavity resonators in the transmitter, a monochromatic wave having a wavelength of 5 to 6 cm is filtered out, in contrast to the original apparatus, and by the use of a modern silicon detector as receiver the observation is considerably facilitated. This apparatus can be used to show the optical behaviour of electromagnetic waves and demonstrate the phenomena of reflection, refraction, diffraction, interference and polarisation.

The transmitter consists of a dipole spark gap surrounded by a cavity resonator and contained inside a box with insulating lid. A second, tuneable resonator is attached to the box in front and provided with the radiating funnel. The spark gap operates in a kerosene ("paraffin") bath and can be finely adjusted from the outside by means of a screw. It is connected to the source of voltage through two high resistances contained in a separate box. Both boxes are mounted on a common stand rod and provided with connecting leads and plugs.

The receiver is a tuned dipole with a silicon diode mounted on a plastic rod with connecting sockets, and a detachable reflector.

Additionally required:

As source of high tension of 10,000 V: demonstration transformer (562 11/12) with 500 turns primary coil**). Secondary coil with 23,000 turns (562 14/17)

For qualitative demonstration (by amplification of the superimposed 100 c/s signal from the mains voltage supply): Low-frequency amplifier (580 00) and speaker (580 05).

For quantitative measurements: School mirror galvanometer (532 10).

For setting-up:

1 Stand base	300 01
1 Saddle base	300 11

*) H. Anders, Phys. Blätter 1949 H. 7, and Zs. f. Phys. **129**, 45, 1951

**) At 220 V; at 110 V mains voltage coil with 250 turns (562 13)

582 31

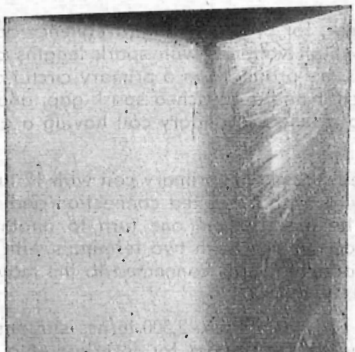
Pair of spare electrodes for the centimetre wave transmitter (582 30).

582 33

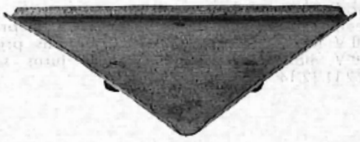
Reflection plate for the centimetre wave transmitter and receiver (582 30), also suitable for acoustic experiments. This plate is used as a "mirror" in a manner analogous to geometrical optics, and for producing standing waves. For a number of experiments the use of two such reflection plates is recommended. Size: 50×50 cm², with provision for mounting on stand rods.

For setting-up:

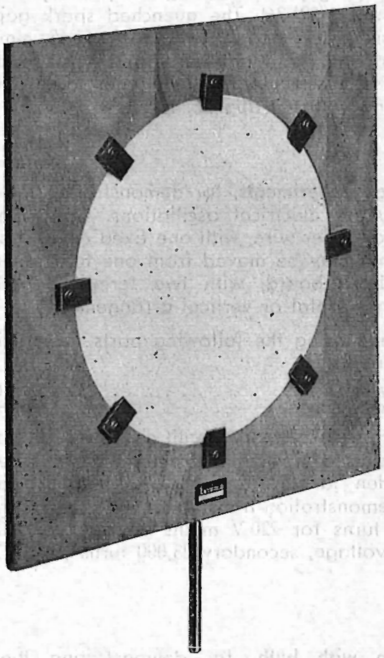
1 Stand rod	300 42
1 Stand base	300 02



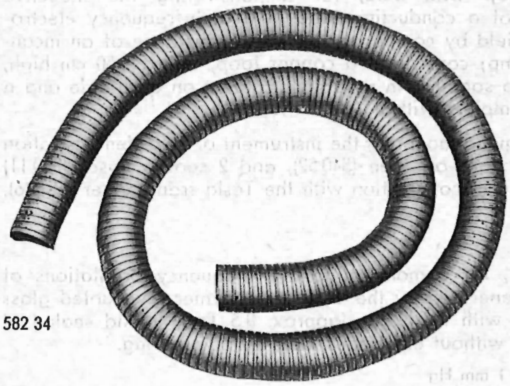
582 35



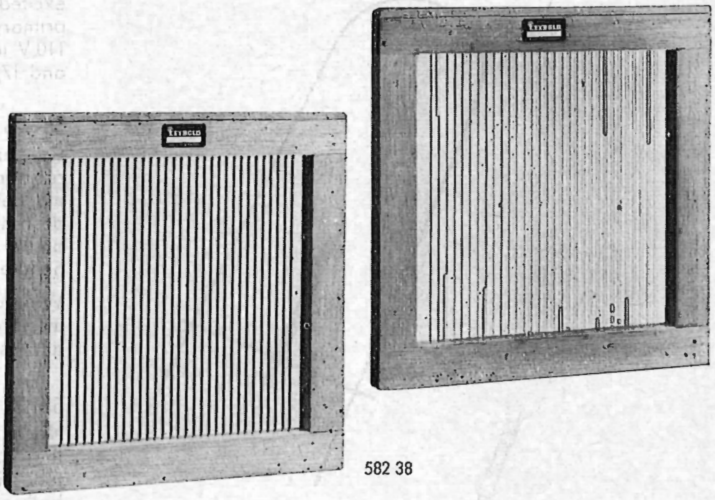
582 37



582 36



582 34



582 38

582 35

Paraffin wax prism, for demonstrating the refraction of short electromagnetic waves with the transmitter and receiver for centimetre waves (582 30). 60° (equilateral) prism with approx. 30 cm long edges; to be mounted on prism table (582 37).

582 37

Prism table for paraffin wax prism; triangular plate with flanged edges for secure support of the prism; designed for mounting on a stand rod.

For setting-up:

1 Stand rod	300 41
1 Stand base	300 01

582 36

Paraffin wax lens, for demonstrating lens action and refraction with short electromagnetic waves. The convex lens is mounted in a wooden frame to prevent disturbing diffraction phenomena; dia. approx. 30 cm, focal length approx. 400 mm; in frame on rod, dia. 12 mm.

For setting-up:

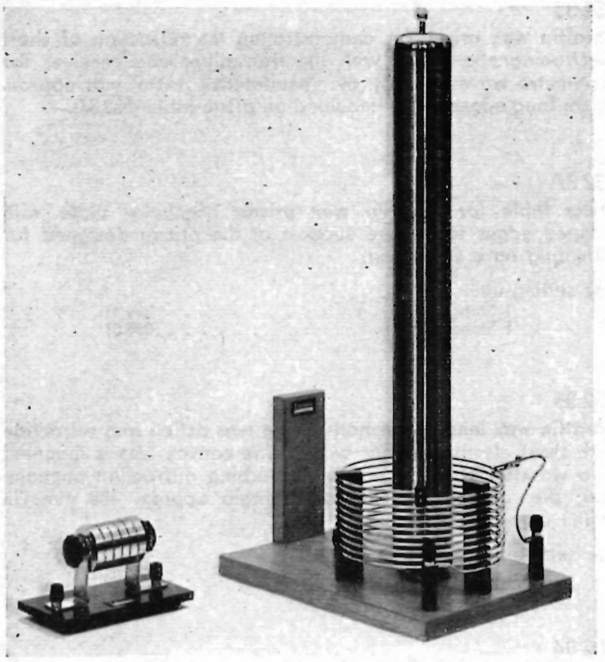
1 Stand base	300 02

582 34

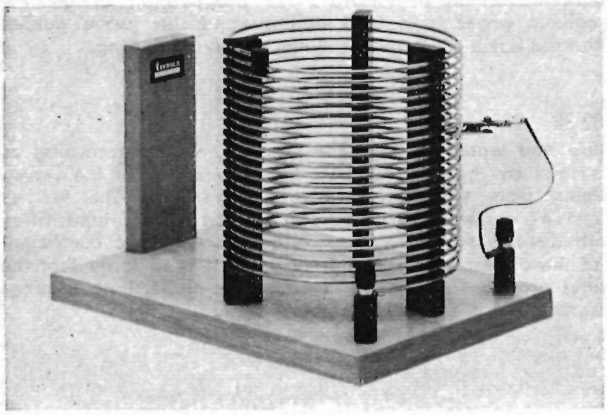
Flexible metal tube for the transmitter and receiver for centimetre waves, to demonstrate the propagation of electromagnetic waves in a bent hollow conductor (wave guide). The tube has a diameter of 50 mm and is 2.5 m long.

582 38

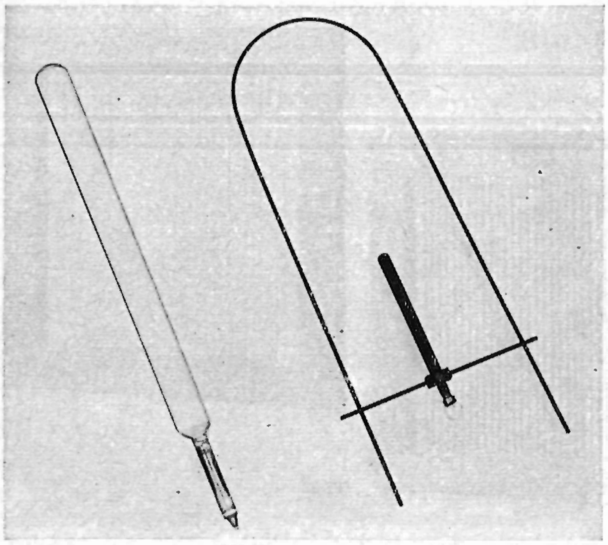
Wire and water grating. The wire grating according to H. Hertz can be used to show the polarisation of the waves issuing from the centimetre-wave transmitter. The water grating described by Cl. Schäfer consists of glass tubes filled with distilled water. Water has a high dielectric coefficient and the displacement current set up in it is so large that the water grating also exhibits a polarising effect. Both gratings are mounted in 26×26 cm² wooden frames.



581 35   581 36



581 37



581 31   581 26

581 36

Tesla transformer, for producing high-frequency damped oscillations at very high voltages with spark lengths of 20–30 cm. The oscillations are produced in a primary circuit consisting of a coil, a capacitor and a quenched spark gap, and transferred by induction to a tuned secondary coil having a great number of turns.

The transformer consists of: primary coil with 12 turns made of thick copper wire, with one fixed connection and one connection that can be moved from one turn to another, on base board, 21×30 cm^2 in size, with two terminals with sockets and one earthing socket which is connected to the mounting socket for the secondary coil.

The secondary coil has approx. 2,500 turns, is about 54 cm long, and has a plug at the bottom for insertion into the earthed mounting socket of the base board, with a spherical electrode on top.

The following parts are recommended for setting-up and exciting the primary oscillation circuit:

1 Leyden jar	544 02
1 Subdivided spark gap	581 35
Demonstration transformer with 500 turns primary coil for 220 V mains voltage, or with 250 turns primary coil for 110 V mains voltage, and 23,000 turns secondary coil (562 11/12/14 or 13 and 17)	

581 35

Subdivided spark gap, for exciting the primary circuit of the Tesla transformer (581 36). The quenched spark gap is 2 mm long, with six disc-shaped electrodes of 45 mm diameter mounted on a common, highly insulating axis. On base plate, 15×8 cm^2 in size, with two terminals with sockets for connection. Operating voltage: approx. 10,000 V.

581 37

Coil for Lodge experiments, for demonstrating the resonance of high-frequency electrical oscillations. Coil with 20 turns made of thick copper wire, with one fixed connection and one connection that may be moved from one turn to another; on 21×30 cm^2 base board, with two terminals with sockets; suitable for horizontal or vertical arrangement.

We recommend using the following parts for making up the oscillatory circuit:

Leyden jar	544 02
Glow lamp	505 38

For excitation, an oscillatory circuit consisting of the following parts may be used: Tesla transformer without secondary coil (581 36), Leyden jar (544 02), subdivided spark gap (581 35), excited by demonstration transformer with the following coils: primary 500 turns for 220 V mains voltage, or 250 turns for 110 V mains voltage, secondary 23,000 turns (562 11/12/14 or 13 and 17).

581 26

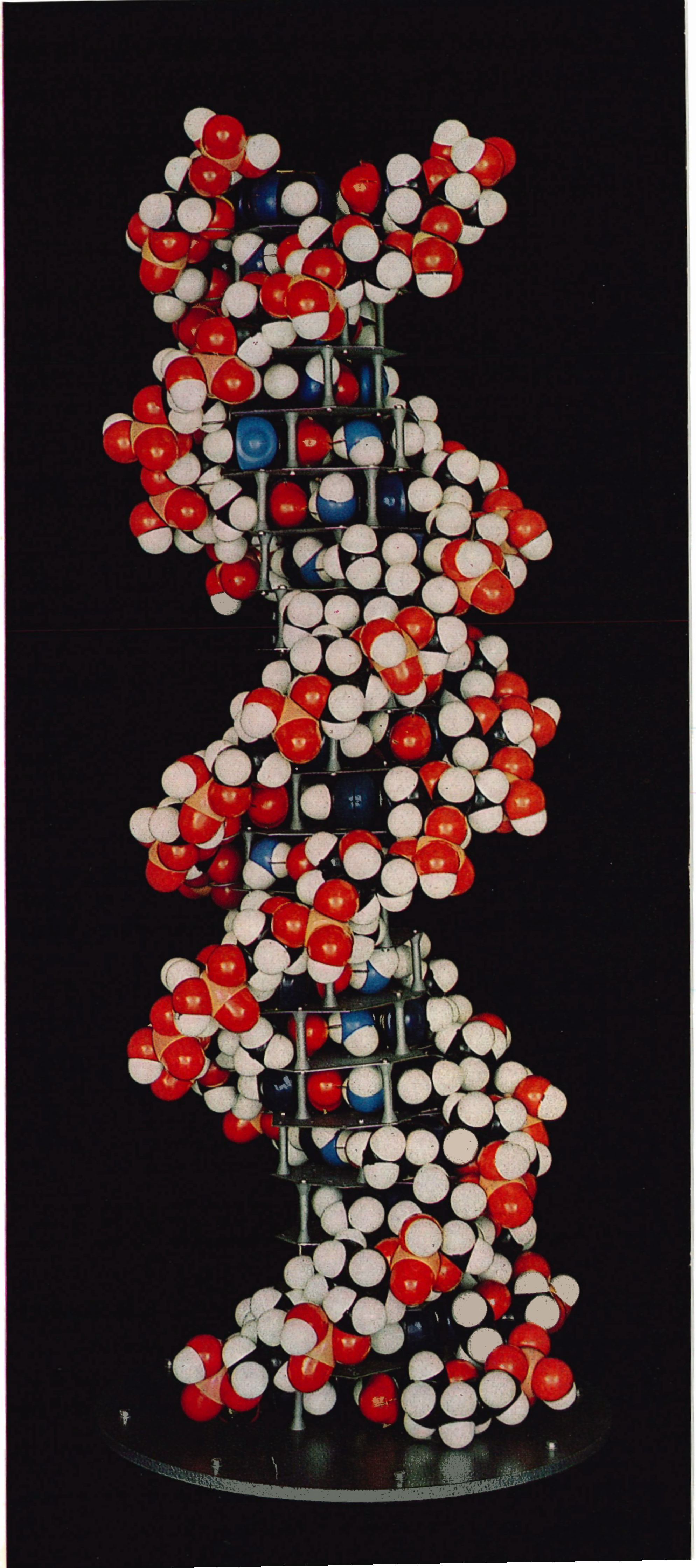
Copper loop with bulb, for demonstrating the inductive reactance of a conducting loop in a high-frequency electromagnetic field by comparison with the resistance of an incandescent lamp; consists of a copper loop, approx. 50 cm high, and a lamp socket with a straight contact on each side and a handle; complete with 6 V, 5 W bulb.

We recommend mounting the instrument on two demonstration insulators, stand-off type (540 52), and 2 saddle bases (300 11) and using it in conjunction with the Tesla transformer (581 36).

581 31

Neon tube, for demonstrating high-frequency oscillations of the type generated by the Tesla transformer. Evacuated glass tube filled with neon gas [approx. 0.5 Torr*)] and sealed at both ends, without electrodes, approx. 50 cm long.

*) 1 Torr = 1 mm Hg



Model of a DNS molecule, made up from the atom models designed by Stuart and Briegleb. Desoxyribonucleic acid is a constituent of cellular nuclei. The genes, in particular, consist of this compound.

PLATE X

ATOMIC AND NUCLEAR PHYSICS

Nowadays introductory experiments on atomic and nuclear physics form part and parcel of modern physics teaching. They evoke to quite a special extent the interest of young people who rightly expect physics teaching to show them a glimpse of the present-day state of knowledge. But they present the teacher with novel physical and didactic questions. In this field especially, scientific research has made very great advances within the last decades. Many natural phenomena of entirely new kinds have been discovered which could not in any way have been predicted beforehand. For the interpretation of these microphysical processes it became necessary to find modes of thinking that were, to a great extent, radically different from traditional and time-honoured ideas. The central one of these was the quantisation of energy.

School teaching can by the very nature of things follow such developments in research only with a considerable time lag. This is particularly true of atomic and nuclear physics. On the other hand, just this field of physics provides particularly deep insights into the ways physical insights are gained and into the influence of physics upon the thoughts and actions of mankind, and this is vitally important in general education.

We have, therefore, been for years working out suggestions for new apparatus and experiments which would help in making modern physical developments accessible to teaching. In the following section of the catalogue we present those items of our apparatus suitable for an introduction to atomic and nuclear physics. In their design we have been guided by the rules that apply to physics teaching in general. Apparatus originally, and often for one experiment only, are not suitable for teaching.

The experimental arrangements must be clear and simple. The relationships under investigation must not be overshadowed by other phenomena that are irrelevant in that particular context. Again, we deemed it important to construct the apparatus, if possible, in such a manner that measurements can be performed with it. The teacher can then at his own free will use the experiment as a qualitative demonstration or use it to obtain quantitative results. Most of the experiments can, moreover, be performed by the pupils themselves in practical work.

We continuously improve and develop these experiments and apparatus to keep up with the advances of science. In consequence the lists of apparatus only quote the most recent versions. Nevertheless the older equipment can still be used for most experimental arrangements.

Some of the apparatus listed in the following will also be found in other parts of the catalogue, as is indicated by their catalogue numbers. Here, they are grouped in the following order:

1. **Kinetic theory of gases**
   a) Model experiments
   b) Brownian motion
   c) Separation column
2. **Field-emission electron microscope**
3. **The fine-beam tube and the determination of the charge-to-mass ratio e/m of the electron**
4. **Photoelectric effect and the determination of Planck's constant h**
5. **Observation of quantised energy transitions using electron collisions in the arrangement devised by J. Franck and G. Hertz.**
6. **Generation of X-rays**
7. **Detection and measurement of radioactivity**
   a) Scintillation
   b) Pocket dosimeter
   c) Wulf electroscope
   d) Electronic scalers
   e) Measuring amplifier
   f) Cloud chambers
   g) Nuclear emulsion plates
   h) Radioactive sources
   i) Experiments on radioactive decay
8. **Experiments on artificial radioactivity**
9. **Molecular models**
10. **Crystal lattice models**
11. **Periodic system of elements**

1. Kinetic theory of gases

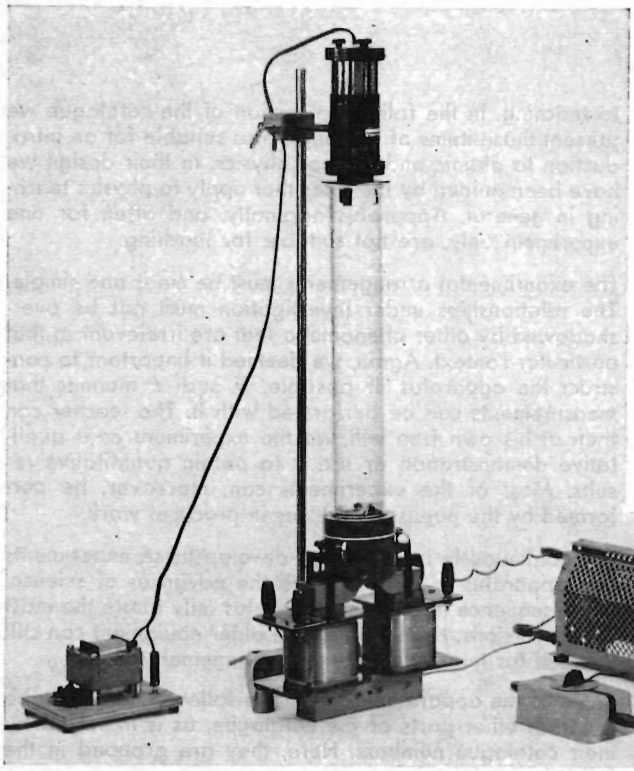


Fig. 98 Model experiment on the kinetic theory of gases, experimental arrangement. PH 2015

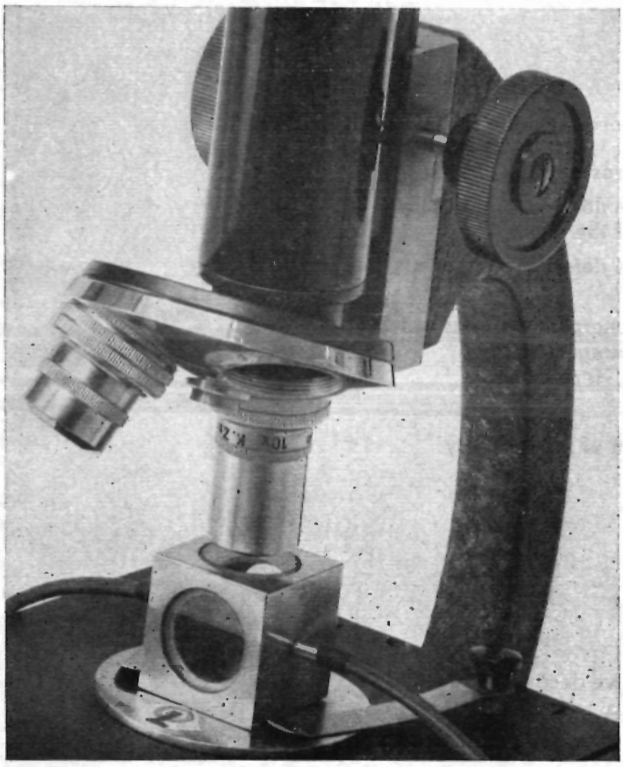


Fig. 99 PH 2016
Observation of Brownian motion in the smoke chamber with a microscope.

1.a, Model experiments on the kinetic theory of gases

376 01

Model experiment on the kinetic theory of gases
For illustrating the thermal motion of molecules and atoms in a gaseous mixture exposed to the gravitational field of the earth, and to demonstrate the transformation of a gas into the liquid and, ultimately, the solid state.

Colourless and coloured glass beads of 5–10 mm diameter form the "model gas". These can be set in more or less vigorous motion in a glass cylinder mounted vertically on an oscillating system with electromagnetic excitation. The oscillating system is tuned to a natural frequency of 100 c/s and is set oscillating by a field that alternates with the mains frequency.

The glass cylinder, dia. approx. 65 mm, height 40 cm, is closed by a transparent plastic lid. The pole-pieces of the apparatus are mounted on the plane ground top faces of the arms of the U-core of our demountable demonstration transformer wired up as an electromagnet and retained there by means of the fixing clamps supplied with it.

For better visibility, the tube should be illuminated from above.

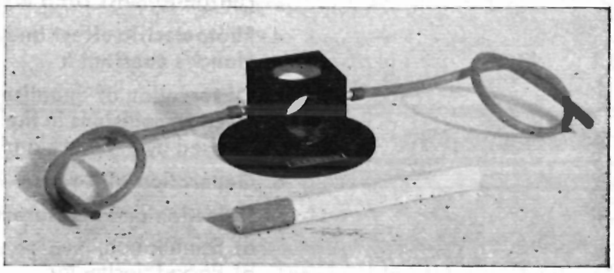
As illuminating device we recommend:

Lamp house	450 60
Lamp, 6 V, 30 W	450 51
Single-lens condenser	460 17
Stand base, length of sides 20 cm	300 02
Stand rod, 75 cm long	300 43
Leybold boss	301 01
Transformer, 6 V, 30 W	562 76

For the electromagnet, the following parts of the demountable demonstration transformer are required:

U-core . . . from	562 11
For 220 V, 50 c/s mains 1)	
2 Coils with 500 turns	562 14
Rheostat, 320 Ω	537 23
For 110 V, 50 c/s mains 1)	
2 Coils with 250 turns	562 13
Rheostat, 110 Ω	537 24

1) The equipment is unsuitable for 60 c/s mains.



372 51

1.b, Brownian motion

372 51

Smoke chamber, for observing Brownian motion of smoke particles in dark-field illumination. The chamber, a hollow cube of approx. 25 mm edge length with base, has two lateral illuminating windows and an observation window on top. The smoke is blown into one of the two nipples by means of the rubber tube supplied with the instrument.

This requires a microscope with approx. 100fold magnification, objective max. ×30, e.g. microscope 442 13, and an illuminating device (516 02) see p. 80.

1.c, Separation columns

In science and technology, separation columns are used to separate isotopes. They permit the separation of gaseous isotopic mixtures, the constituents of which are not different chemically, but differ only physically in their atomic weight. The procedure employed in the separation column is based on the separating-out effect that occurs in a gaseous mixture across which a thermal gradient exists, and which is known as thermal diffusion. One manifestation of this effect is the well-known fact of dust settling above the radiators and tubes of central heating installations, where the heavy dust particles collect on the cool walls opposite or above the heater.

In the separation column developed by CLUSIUS, the temperature gradient is horizontally directed. A heating wire is extended along the axis of the vertically arranged tube and heats the interior of the tube, the outside of it being cooled.

The thermal diffusion effect will then cause a separation of the constituents of the gas which, however, is not complete because there is always some back diffusion. In the end a state of equilibrium will be established where the population of molecules of smaller molecular weight will be enriched on the warm side. Inside, it contains a second glass tube concentric with the enriched on the cold side. This effect is very feeble and difficult to demonstrate experimentally. However, it is multiplied and rendered technically exploitable by the combination, used by CLUSIUS, with a convection current in the gas known as thermosyphon effect. The horizontal density gradient bound up with the thermal gradient gives rise to a vertically directed current in which the gas particles ascend on the warm side and descend on the cold. In this manner, the light particles are preferentially transported up and the heavier ones down. At the top and bottom, finally, they collect with increasing purity and can be tapped off from there in a pratically pure state.

372 45

Model separation column

The model illustrates the mode of action of a separation column. It consists of a glass tube of approx. 80 cm length and 2 cm diameter which is cooled by the ambient air on the outside. Inside, it contains a second glass tube concentric with the first which is provided with a heating filament. The annular space between these two tubes contains a light brown mixture of bromine vapour and air, instead of an isotopic mixture. After some minutes of operation, the lower part of the tube contains almost pure, brown bromine, and the upper one colourless air. The model separation column is screwed into an E 14 lamp socket in front of a white, varnished wooden board of approx. 1 m length and 9 cm width. The wooden board is provided with a device for fastening to stand material.

The lamp socket is provided with an 80 cm long two-core cable with 4 mm plugs for connection to the heating voltage (20 V, 6 A). Without source of voltage or stands.

We recommend:

1 U-core with yoke	562 11
1 Clamping device	562 12
1 Coil with 500 turns (if the mains voltage is 220 V)	562 14
or:	
1 Coil with 250 turns (if the mains voltage is 110 V)	562 13
1 Coil with 46 turns	562 18
1 Stand base	300 01
1 Stand rod, 1 m long	300 44

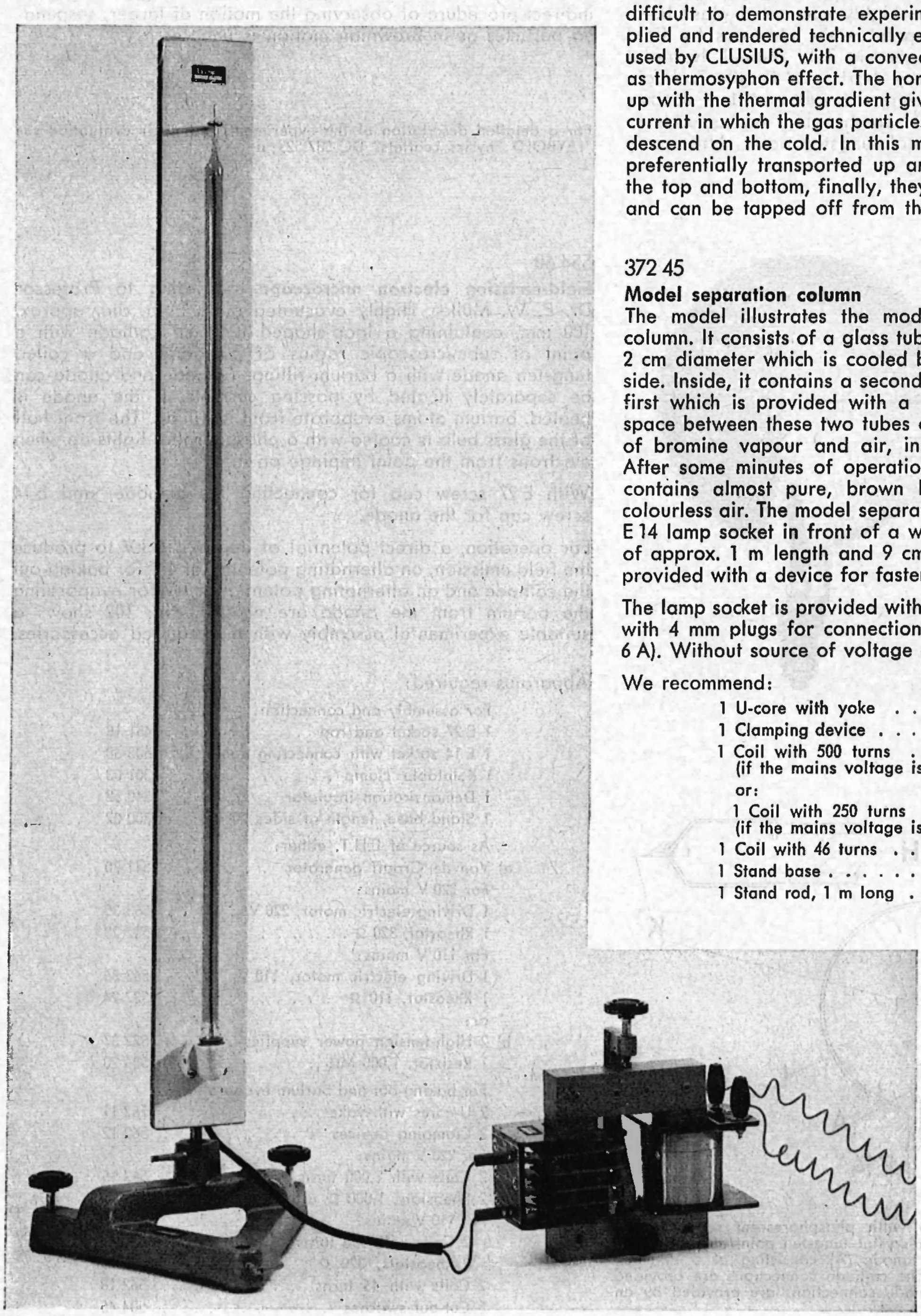


Fig. 100

PH 2014

Fig. 100
The model separation column set up for an experiment.

2. Field-emission electron microscope

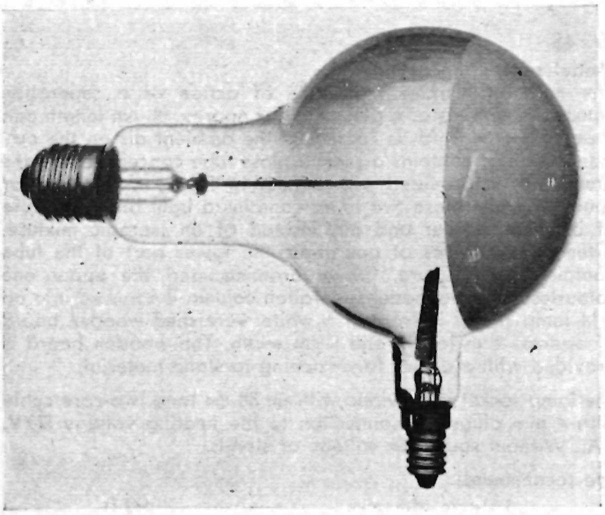
for observing individual atoms and their thermal motion

With the field-emission electron microscope the largest magnifications that have so far been possible can be obtained. The field-emission electron microscope attains magnification of approx. 500,000, with a resolution of 2×10^{-9} m. But in spite of this high power the instrument is very simple in design. Therefore it is eminently suitable in teaching for direct demonstration of the atomic structure of matter and enables even the thermal motion of atoms to be observed.

A fine tungsten point with submicroscopic radius of curvature is arranged at the centre of a highly evacuated glass bulb. When E.H.T. is applied, this point emits electrons by field emission. The inhomogeneous electric field around the point acts like an electron lens of very short focal length. To begin with, a pattern of regularly arranged bright and dark patches is seen on the phosphorescent screen, which corresponds to the structure of the single-crystal tungsten point. After some barium atoms have been deposited on the tungsten point their corresponding image points become visible owing to the greater electron emission of the barium atoms. When the tungsten point is heated, the barium atoms participate in the ensuing thermal motion. This can be seen from the vigorous agitation of their image points on the phosphorescent screen.

Owing to the extremely large magnification the field-emission electron microscope permits a direct glimpse of the world of atoms and their thermal agitation to be caught. Thus, the indirect procedure of observing the motion of larger, suspended particles as in Brownian motion is unnecessary.

For a detailed description of the experiments and their evaluation see "LEYBOLD Physics Leaflets" DC 537.525; a–c.



554 60

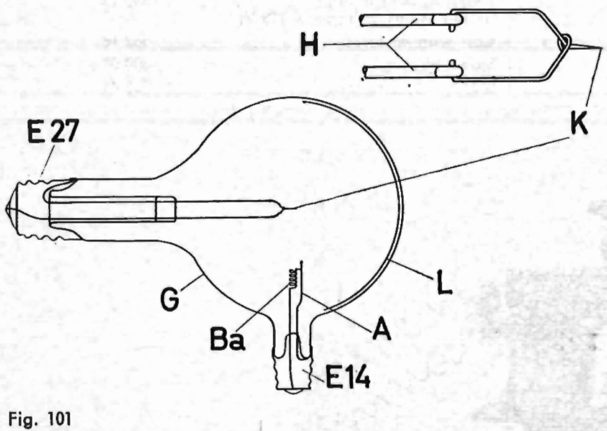


Fig. 101
Highly evacuated glass bulb (G) with phosphorescent screen (L), a cathode (K) made of a fine single-crystal tungsten point mounted on a tungsten wire loop (H), and an anode (A) consisting of a tungsten filament with barium store (Ba). The cathode connections are provided by an E 27 screw cap and the anode connections are provided by an E 14 screw cap.

554 60

Field-emission electron microscope, according to Professor Dr. E. W. Müller. Highly evacuated glass bulb, dia. approx. 100 mm, containing a loop-shaped tungsten cathode with a point of submicroscopic radius of curvature and a coiled tungsten anode with a barium filling. Cathode and anode can be separately heated by passing currents. If the anode is heated, barium atoms evaporate from its filling. The front half of the glass bulb is coated with a phosphor that lights up when electrons from the point impinge on it.

With E 27 screw cap for connecting the cathode, and E 14 screw cap for the anode.

For operation, a direct potential of approx. 10 kV to produce the field emission, an alternating potential of 4 V for baking-out the cathode and an alternating potential of 1 V for evaporating the barium from the anode are needed. Fig. 102 shows a suitable experimental assembly with the required accessories.

Apparatus required:

For assembly and connection:	
1 E 27 socket and rod	451 18
1 E 14 socket with connecting cable	505 68
1 Rotatable clamp	301 03
1 Demonstration insulator	540 52
1 Stand base, length of sides 20 cm	300 02
As source of E.H.T. either:	
a) Van de Graaff generator	541 70
For 220 V mains:	
1 Driving electric motor, 220 V	563 35
1 Rheostat, 320 Ω	537 23
For 110 V mains:	
1 Driving electric motor, 110 V	563 36
1 Rheostat, 110 Ω	537 24
or:	
b) 2 High-tension power supplies	522 37
1 Resistor, 1,000 MΩ	536 23
For baking-out and barium evaporation:	
2 U-cores with yoke	562 11
2 Clamping devices	562 12
For 220 V mains:	
2 Coils with 1,000 turns	562 15
2 Rheostats, 1,000 Ω	537 22
For 110 V mains:	
2 Coils with 500 turns	562 14
2 Rheostats, 320 Ω	537 23
2 Coils with 46 turns	562 18
3 Cut-out switches	504 45

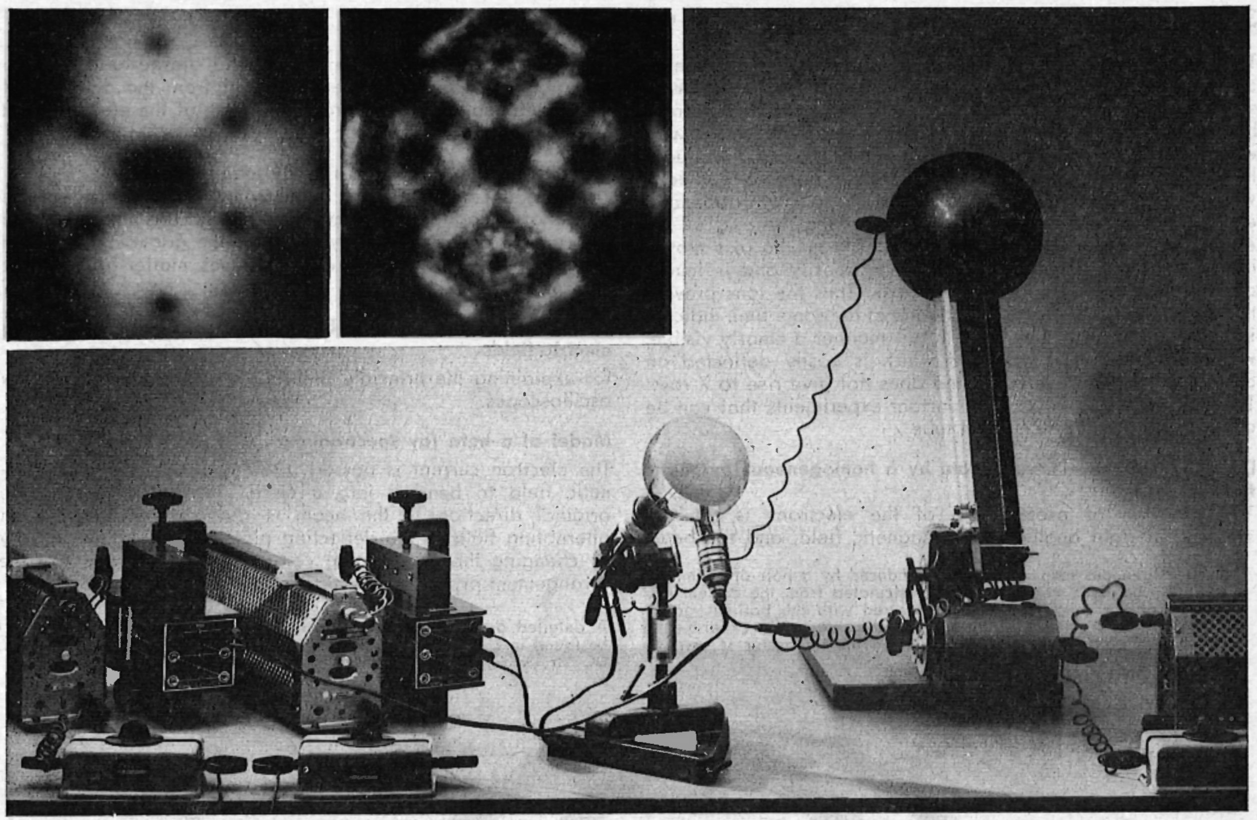


Fig. 102 **Arrangement for demonstrations with the field-emission electron microscope**
Upper left: Image of the pure single-crystal tungsten point;
Upper right: Image of the single-crystal tungsten point with barium atoms deposited on it.

PH 2058

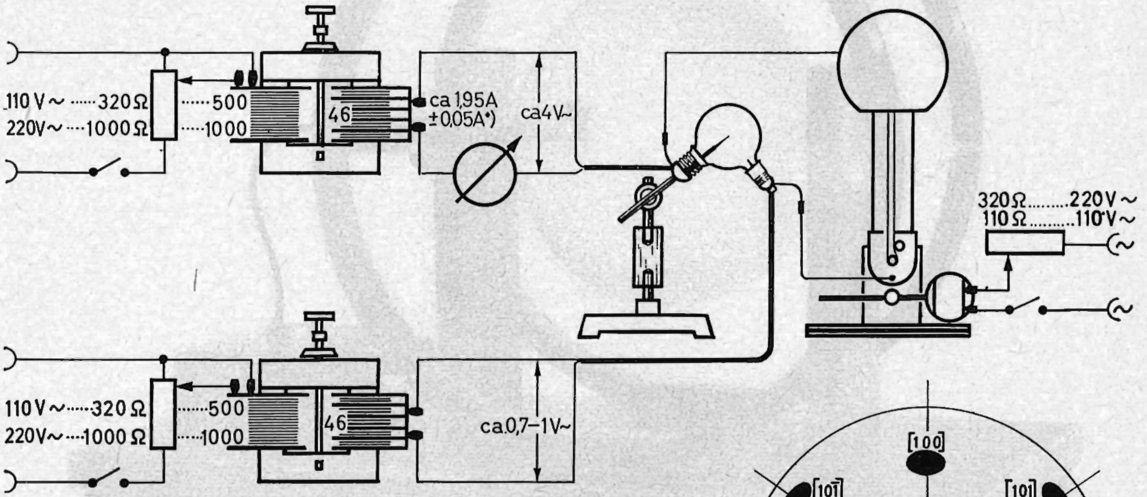
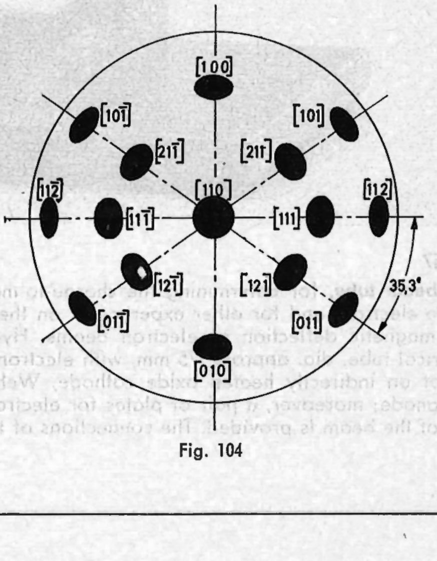

110 V ~ ······ 320 Ω
220V~ ···· 1000 Ω
······ 500
····· 1000
46
ca 1,95A
± 0,05A*)
ca4V~
320 Ω .... 220 V ~
110 Ω .... 110 V ~
110 V ~····· 320 Ω
220V~···· 1000 Ω
······ 500
····· 1000
46
ca.0,7–1V~

Fig. 103 **Circuit diagram for assembling the field-emission electron microscope**
*) The Directions for Use should be carefully studied


[100]
[10̄1]
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[110]
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[111]
[12̄1]
[121]
35,3°
[01̄1]
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[010]

Fig. 104

Fig. 104 The crystal directions of the tungsten lattice appearing on the phosphorescent screen of the field-emission electron microscope, seen in parallel projection.
Cf. the crystal lattice model of tungsten (A 2: 320 002), see prospectus "Lattice structures" PH 48-2.

3. The fine-beam tube and the determination of the charge-to-mass ratio e/m of the electron

The laws of motion of electrons in electric and magnetic fields can be demonstrated particularly clearly with a gas-focussed electron beam. This gas-focussed electron beam is a narrow beam of electrons and occurs in partially evacuated tubes with very accurately adjusted gas pressure. Along its path it produces heavy (and thus comparatively immobile) positive gas ions whose concentration is greatest where the concentration and energy of the electrons is greatest, i.e. along the axis of the electron beam. An electron that deviates from the axis moves into a region of lower positive charge density and is immediately attracted back towards the axis. Thus the ions prevent the diffusion of the electron beam and at the same time indicate its path by the glow they emit. In this manner a clearly visible, well-defined beam is obtained which is easily deflected on account of its small velocity, and does not give rise to X-rays. The following are the most important experiments that can be carried out with the fine-beam tube:

Deflection of the electron beam by a homogeneous magnetic field

The direction of propagation of the electrons is, at any moment, at right angles to the magnetic field, and the beam is deflected into a complete circle. The charge-to-mass ratio of the electron, e/m, can be calculated from the diameter of the circular path, the accelerating voltage of the electrons and the intensity of the magnetic field[1]).

Deflection of an electric current by magnetic fields

The experiments, important in elementary instruction, on the effects of a magnetic field upon an electric current can here be shown with particular clarity, because the gas-focussed beam represents a to all intents and purposes matter-free electric current.

Deflection of an electron beam by steady and alternating electric fields

for explaining the principle of Braun's tubes and cathode ray oscilloscopes.

Model of a beta ray spectrometer

The electron current is passed through a homogeneous magnetic field to bend it into a circle. At the same time the original direction of the beam is changed by applying an alternating field to the deflecting plates, or its initial velocity by changing the accelerating voltage. It will be seen that the arrangement produces direction- and velocity-focussing effects.

A detailed description of the measurements and their evaluation will be found in "LEYBOLD Physics Leaflets", DC 537.12; a, DC 537.533.31; d, DC 537.533.32; a and DC 537.533.355; a.

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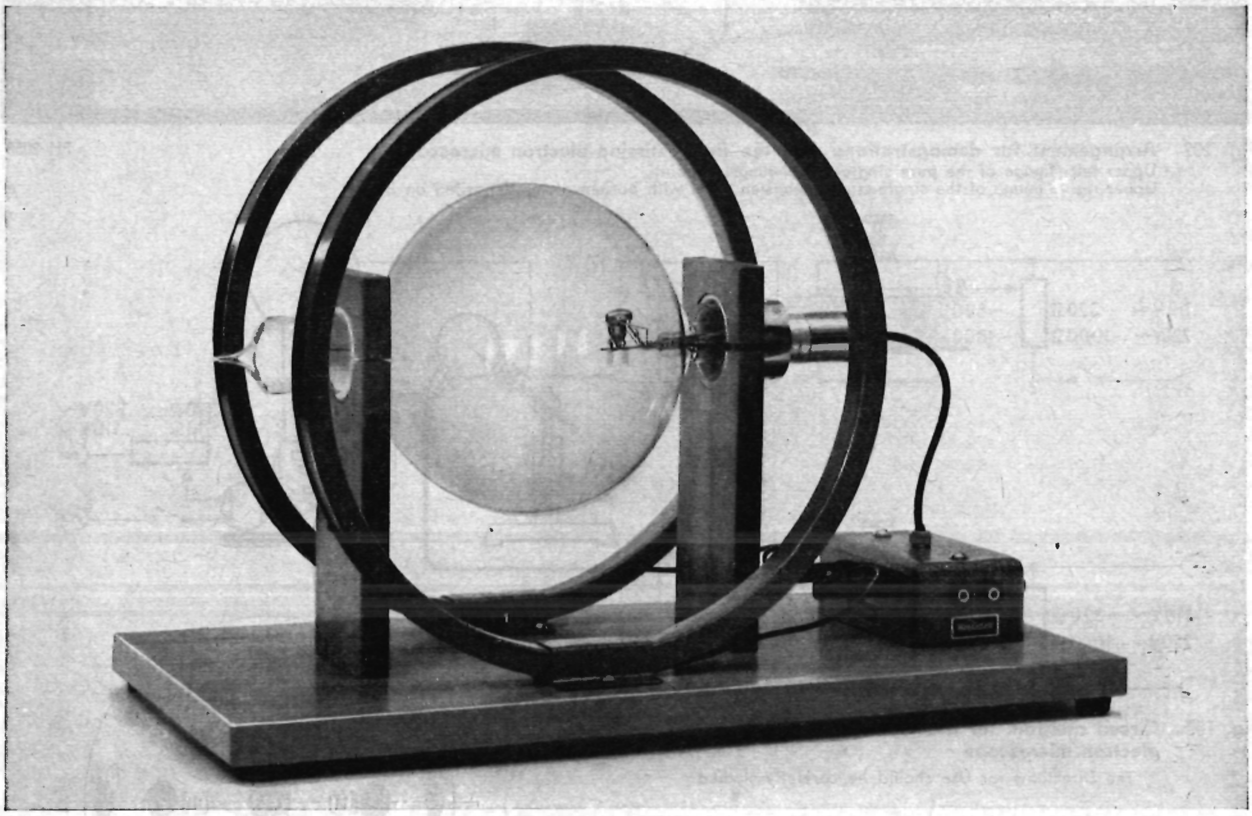
[1]) The homogeneous magnetic field is produced by a pair of Helmholtz coils. The magnetic intensity can be calculated from the current and the data of the coils, or directly measured with the ballistic galvanometer, while the measurement of beam diameter poses experimental problems of great educational value when the apparatus is used by the pupils.



555 57/58

555 57

Fine-beam tube, for determining the charge-to-mass ratio e/m of the electron, and for other experiments on the electrostatic and magnetic deflection of electron beams. Hydrogen-filled, spherical tube, dia. approx. 175 mm, with electron gun consisting of an indirectly heated oxide cathode, Wehnelt cylinder and anode; moreover, a pair of plates for electrostatic deflection of the beam is provided. The connections of the electrodes and of the deflecting plates are led out to a 6-pole valve cap. The pressure in the tube is so adjusted that the electron beam produced by this gun remains sharply focussed along its entire length at an anode voltage of 200–300 V.

We recommend using the base-board with Helmholtz coils for assembly and making electric connections. The other necessary accessories are listed overleaf.

555 58

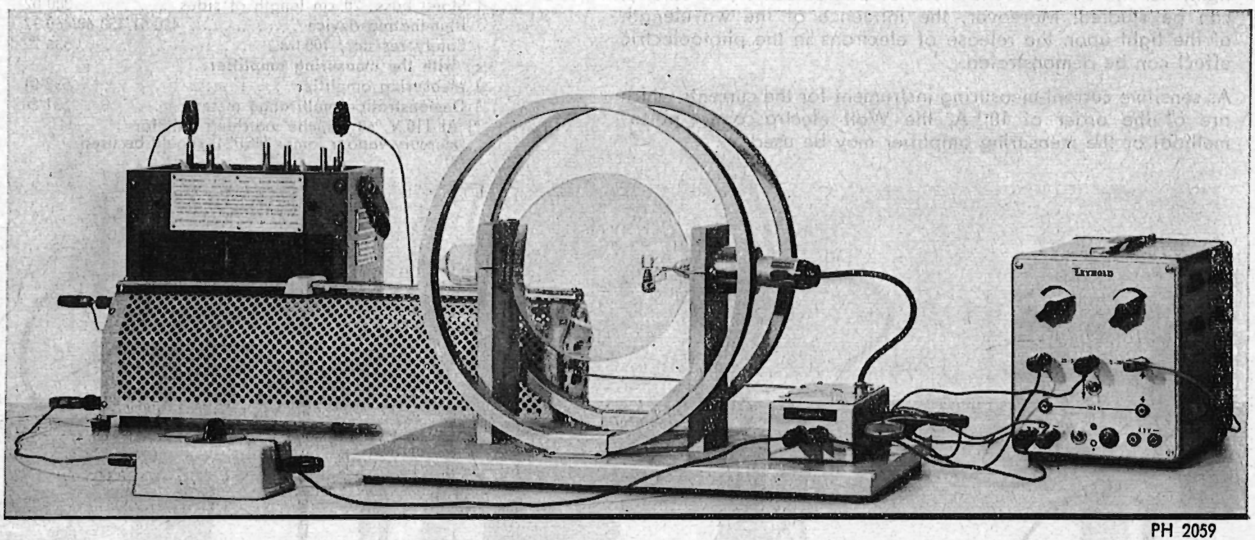
Base board with Helmholtz coils, for mounting the fine-beam tube and making electric connections to it, and for producing a homogeneous magnetic field for determining *e/m*. The electric connection sockets for cathode, anode, Wehnelt cylinder, heating filament and electrostatic deflecting plates are provided in a box from which a multiple-core cable ending in a 6-pole valve socket fitting the tube comes out. Moreover, this box contains suitable protective resistors to limit the emission current.

The Helmholtz coils consist of 2 circular coils, each of 130 turns and 150 mm radius, arranged parallel to one another and spaced 150 mm apart. They can be loaded up to approx. 5 A.

Terminal box and Helmholtz coils are mounted on a base-board, 50×25 cm² in size, which is moreover provided with two supports with felt-lined openings to hold the fine-beam tube.

Additionally required apparatus:

For operating the tube:	
1 Power supply	522 35/33
For measuring *e/m*:	
1 Accumulator	522 73
1 Rheostat, 11 Ω	537 26
2 Meters, one for direct currents up to about 2 A, the other for direct potentials of up to about 300 V, e.g.	
2 Demonstration multirange meters	531 86
For electrostatic deflection of the beam:	
1 Potentiometer, 100 Ω	537 85
1 Crossover switch	504 49
or:	
1 Rheostat, 1,000 Ω	537 22
1 U-core with yoke	562 11
1 Clamping device	562 12
For 220 V mains:	
1 Coil with 1,000 turns	562 15
1 Coil with 500 turns	562 14
or, for 110 V mains:	
2 Coils with 500 turns	562 14
For magnetic deflection: a permanent magnet, e.g.	
1 Pair of disc magnets	563 19



PH 2059

Fig. 105 Experimental arrangements for determining the charge-to-mass ratio of the electron *e/m* with the fine-beam tube

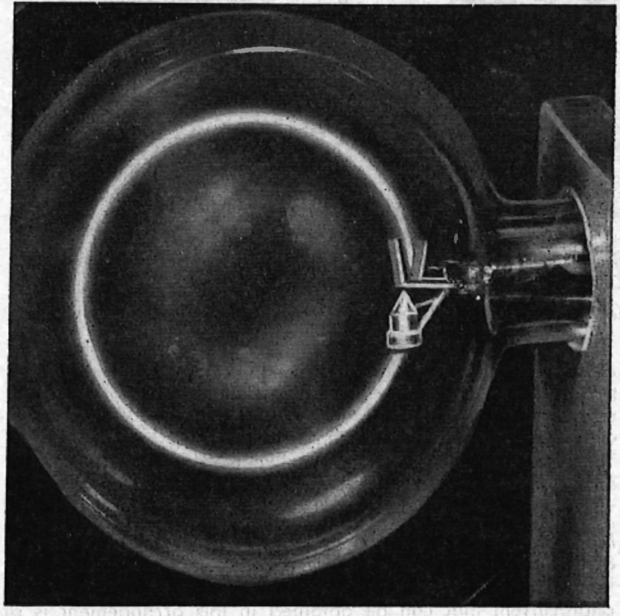


Fig. 106 PH 2060

Gas-focussed electron beam in the homogeneous magnetic field of a pair of Helmholtz coils

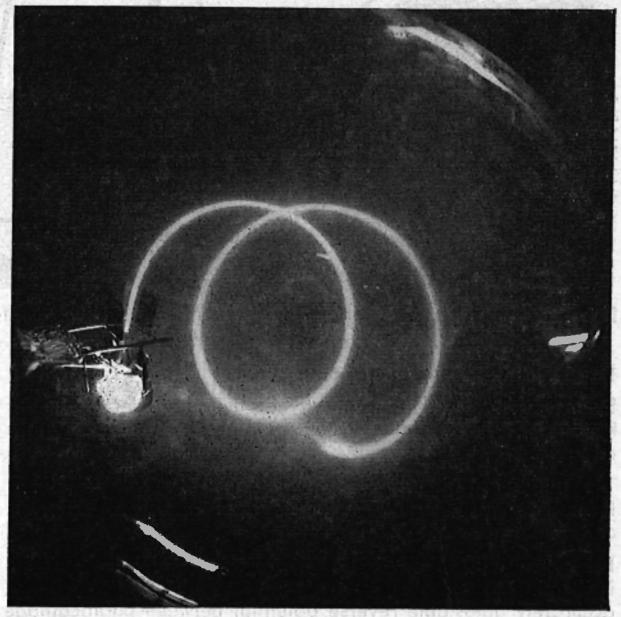


Fig. 107 PH 2061

Helical path of an electron beam in a homogeneous magnetic field

Photo: Dr. Herbert W. Franke, Kreuzpullach/Germany

4. Apparatus for demonstrating the photoelectric effect and for determining Planck's constant h

The photoelectric effect is one of the basic phenomena of modern physics. Its interpretation was given by A. Einstein in 1905 and brings it into close relation with Planck's quantum theory. Therefore the experimental treatment of the photoelectric effect is of particularly great importance for an introduction to quantum physics.

The photoelectric effect

The photoelectric effect or photo-emission which is utilised in practice photocells, can be studied in various experimental arrangements. The simplest way is to illuminate the amalgamated surface of a zinc cathode with a mercury lamp and measure the emitted electrons with a sensitive current-measuring instrument. Even in this simple arrangement the dependence of the emitted electron current upon the intensity of the incident light, i.e. the simple foundations of photoelectric photometry, can be studied. Moreover, the influence of the wavelength of the light upon the release of electrons in the photoelectric effect can be demonstrated.

As sensitive current-measuring instrument for the currents which are of the order of 10^{-8} A, the Wulf electroscope ("pulse" method) or the measuring amplifier may be used.

Apparatus required, cf. Fig. 108:

For the photoelectric effect:	
1 Zinc plate	546 31
1 Pair of spiral electrodes	546 29
1 Demonstration insulator	540 52
1 Mercury vapour lamp	451 15
1 Universal choke, 220 V, 50 c/s *)	451 22
or:	
Demonstration transformer as choke	562 11/12/15
Stands	
As source of voltage:	
1 High-tension power supply	522 37
1 Electroscope	540 09
or:	
1 High-tension voltmeter	540 39
For detection with the Wulf electroscope:	
1 Wulf electroscope	546 00
1 Projection attachment	546 02
1 Stand base, 20 cm length of sides	300 02
Illuminating device	450 51/450 60/460 17
1 Safety resistor, 100 MΩ	536 22
or with the measuring amplifier:	
1 Measuring amplifier	532 01
1 Demonstration multirange meter	531 86

*) At 110 V, 60 c/s, the matching unit for mercury vapour lamps (451 24) should be used.

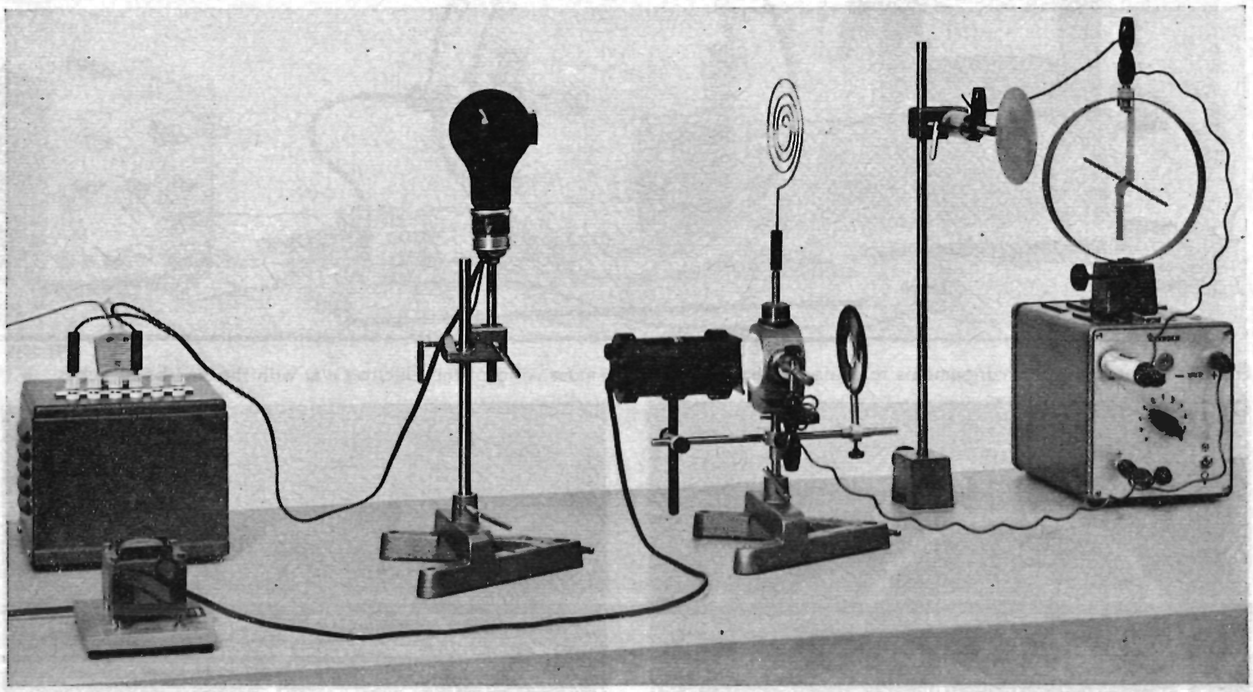


Fig. 108 Experimental arrangement for demonstrating the photoelectric effect with the Wulf electroscope. PH 2062

Determination of Planck's constant,

by measuring the kinetic energy of the photoelectrons as a function of the wavelength of the light by which they are released.

The evaluation of these measurements by means of Einstein's formula leads to a very simple and amply accurate method of determining Planck's constant.

For measuring the kinetic energy, one uses a photocell which is illuminated with monochromatic light and provided with an accurately adjustable reverse potential between photocathode and collector electrode. In this arrangement that value of the reverse potential which brings the photocurrent to zero, that is, just prevents the electrons from reaching the collector electrode, is proportional to the kinetic energy of the electrons. It is not necessary to know the electronic work function of the cathode surface if difference measurements are made with light of different wavelengths.

The result is a linear relation between frequency and kinetic energy from which Planck's constant may be calculated.

The experimental arrangement is shown in Fig. 109, p. 177.

Monochromatic light sufficient both in purity and in intensity can be obtained by dispersing the light of a mercury vapour lamp into a spectrum using the apparatus listed below. The photocurrent that can be obtained in this arrangement is of the order of 10^{-9} to 10^{-11} A. We therefore recommend using the measuring amplifier as a null-instrument of sufficient sensitivity.

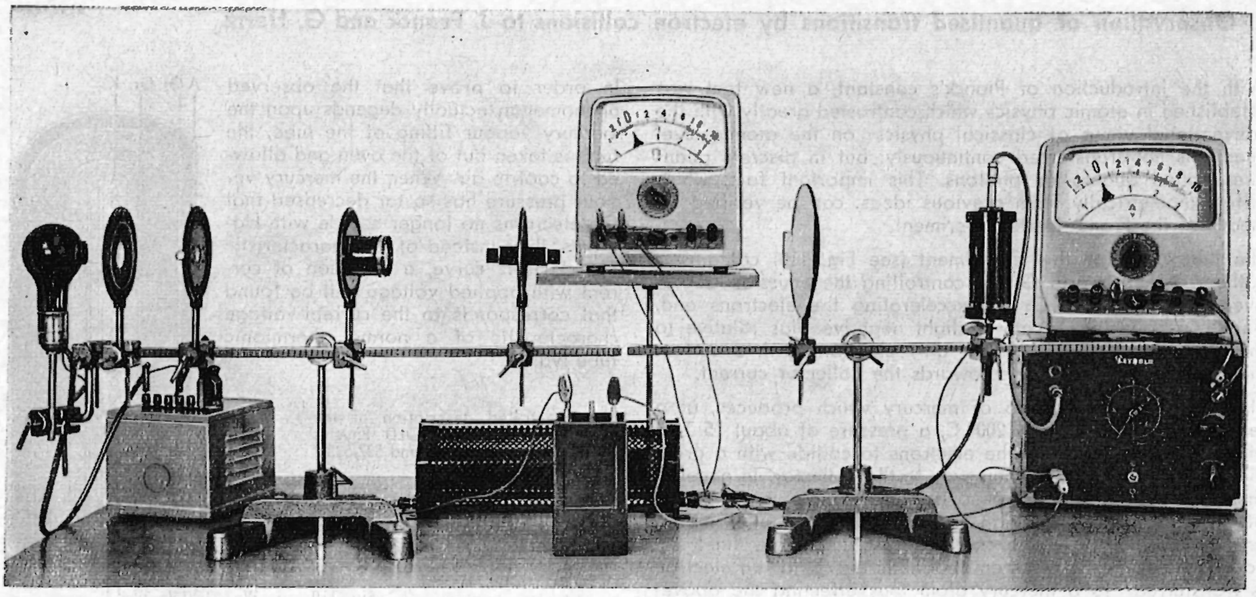


Fig. 109 Experimental arrangement for determining Planck's constant.

PH 2063

Apparatus required, cf. Fig. 109:

For illumination and dispersion into a spectrum:

1 Mercury vapour lamp	451 15
1 Socket on rod	451 18
1 Stand rod, bent through 90°	300 51
1 Universal choke, 220 V, 50 c/s *)	451 22
or:	
Demountable demonstration transformer as choke	562 11/12/15
2 Small optical benches	460 41/42/43
1 Lens in frame, f = 50 mm	460 02
1 Adjustable slit	460 14
1 Projection objective	460 13
1 Direct vision prism	466 05
1 Holder for direct vision prism	466 04
1 Lens in frame, f = 200 mm	460 10
8 Leybold bosses	301 01

For the reverse potential:

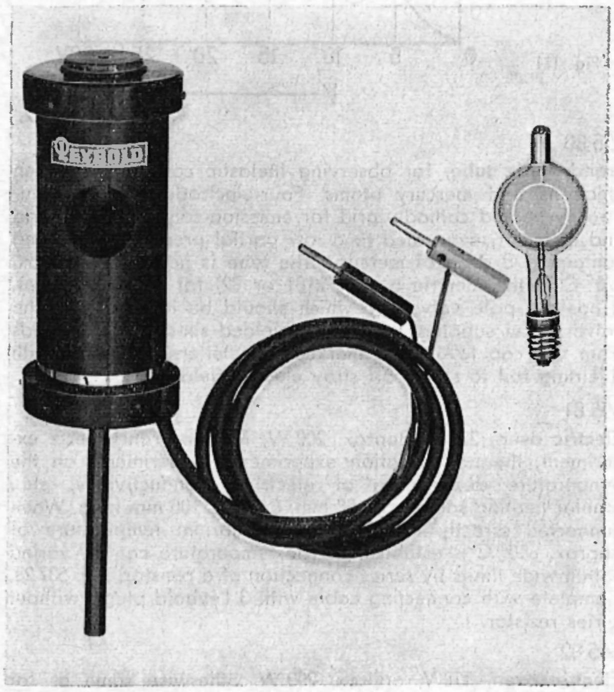
1 Accumulator, minimum voltage: 3 V	522 70/73
1 Rheostat, 320 Ω	537 23
1 Voltmeter, e.g.	
1 Demonstration multirange meter	531 86

For photocurrent and measurement:

1 Photocell for determining *h*	558 77
1 Housing for photocell	558 78
1 Measuring amplifier	532 01
1 Meter, f.s.d. 300 μA, 60 mV; e.g.	
1 Demonstration multirange meter	531 86
or	
1 Demonstration millivolt-microammeter	531 87
Source of current for baking-out, approx. 1 V, 1 A	

*) for 110 V, 60 c/s mains:

1 Ballast unit for mercury vapour lamp	451 24



558 77

Photocell for determining ***h*****,** particularly suitable for measuring the velocity of the released photoelectrons by applying a reverse field. Vacuum photocell with nearly plane, light-sensitive potassium layer and annular collector electrode made of platinum wire. The layer is connected to a metal cap at the upper end of the cell. The annular collector electrode is connected to an E 14 screw cap at its ends and can be baked out by direct passage of current (approx. 1 V, 1 A, required).

We recommend using the cell in housing 558 78.

558 78

Housing for the photocell for determining ***h*****,** for shielding off stray light and electric fields, and for connecting the measuring cable through a highly insulated socket.

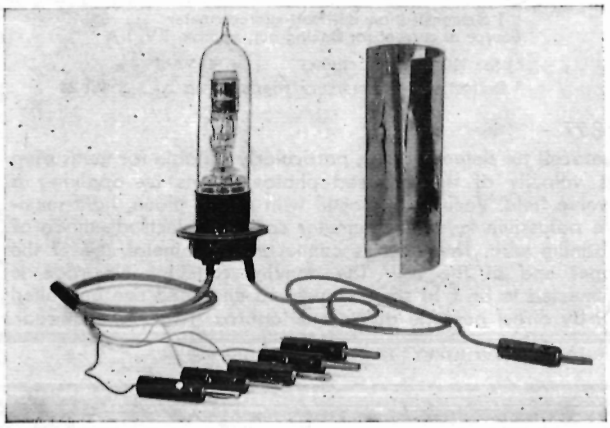
The housing consists of two coaxial cylinders that can be displaced relative to one another, dia. approx. 6 cm. The outer cylinder is closed on top and has an opening for admitting light and a highly insulated socket with spring contact. The inner cylinder contains an E 14 screw socket for screwing in the photocell, which can be centred with three adjusting screws. Attached to the socket is a two-core cable with 4 mm plugs. The housing is mounted on a rod, dia. 10 mm, for setting it up on an optical bench.

5. Observation of quantised transitions by electron collisions to J. Franck and G. Hertz

With the introduction of Planck's constant, a new fact was established in atomic physics which contrasted greatly with the conventional views of classical physics: on the atomic level energy is not transferred continuously, but in discrete quantities called quanta or photons. This important fact, which differs diametrically from previous ideas, can be verified by means of the Franck-Hertz experiment.

The tube used for this experiment (see Fig. 110) contains a cathode K and a grid G_1 for controlling the emission; moreover an anode grid G_2 for accelerating the electrons and, finally, a collector A with a slight negative bias relative to the anode grid to ensure that only electrons with a certain minimum energy contribute towards the collector current.

The tube contains a drop of mercury which produces, at a temperature rather below 200° C, a pressure of about 15 Torr in the tube, thus causing the electrons to collide with a great many mercury atoms on their way to the collector. In general, these collisions are elastic ones. If, however, the kinetic energy of the electrons is just high enough to equal the excitation energy of 4.9 eV of the mercury resonance line, inelastic collisions occur where the entire kinetic energy of an electron is transferred to a mercury atom thus effecting the above-mentioned quantised transition. This is indicated by a distinct drop in the collector current when the critical accelerating voltage is exceeded. If the voltage is increased further, an electron may be accelerated repeatedly to the velocity required for a transfer of its total energy (inelastic collision) to a mercury atom on its way to the collector electrode. Correspondingly, the current-voltage characteristic of the heated tube (Fig. 111) shows characteristic maxima and minima, from whose spacing the excitation voltage of the mercury resonance line and the photon energy required for the transition can be calculated.



555 80

555 81/82

In order to prove that the observed phenomenon actually depends upon the mercury vapour filling of the tube, the tube is taken out of the oven and allowed to cool in air. When the mercury vapour pressure has so far decreased that the electrons no longer collide with Hg-atoms, then instead of the characteristic Franck-Hertz curve, a variation of current with applied voltage will be found that corresponds to the current-voltage characteristic of a normal thermionic tube (valve).

For a detailed description of the experiment, see "LEYBOLD Physics Leaflets" DC 535.352; a and 537.533.9

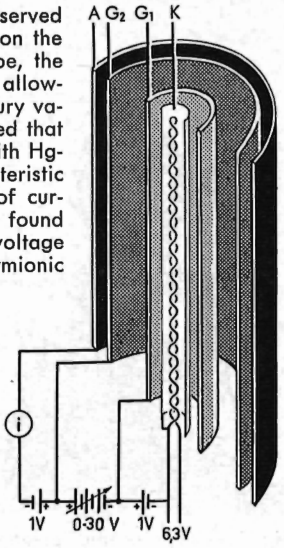


Fig. 110

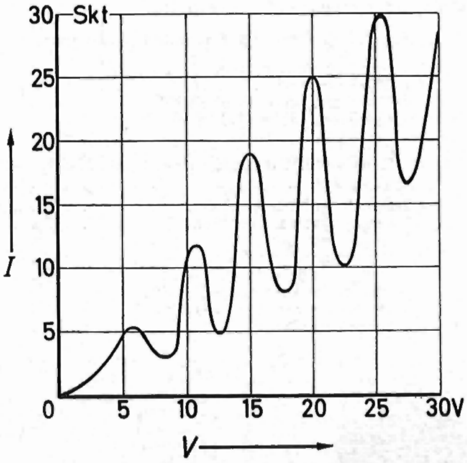


Fig. 111

555 80

Franck-Hertz tube, for observing inelastic collisions between electrons and mercury atoms. Four-electrode tube with indirectly heated cathode, grid for emission-control, anode grid and collector, evacuated to a low partial pressure of air and containing a drop of mercury. The tube is heated to approx. 170° C in the electric oven (555 81 or 82) for the experiment. It has a 7-pole valve cap which should be inserted into the valve socket supplied with it. A shielded six-core cable leads from this cap to 6 plugs marked with letters. Complete with shielding foil to shield off stray electric fields.

555 81

Electric oven, 220 V; approx. 200 W, for the Franck-Hertz experiment, thermal radiation experiments, experiments on the temperature dependence of electrical conductivities, etc.; tubular heating space, dia. 38 mm, approx. 100 mm long. When connected directly to 220 V an equilibrium temperature of approx. 600° C is established. The temperature can be varied within wide limits by series connection of a resistor, e.g. 537 23. Complete with connecting cable with 3 Leybold plugs, without series resistor.

555 82

Electric oven, 110 V, approx. 200 W, otherwise same as for 555 81; rheostat 537 24 is suitable for temperature control.

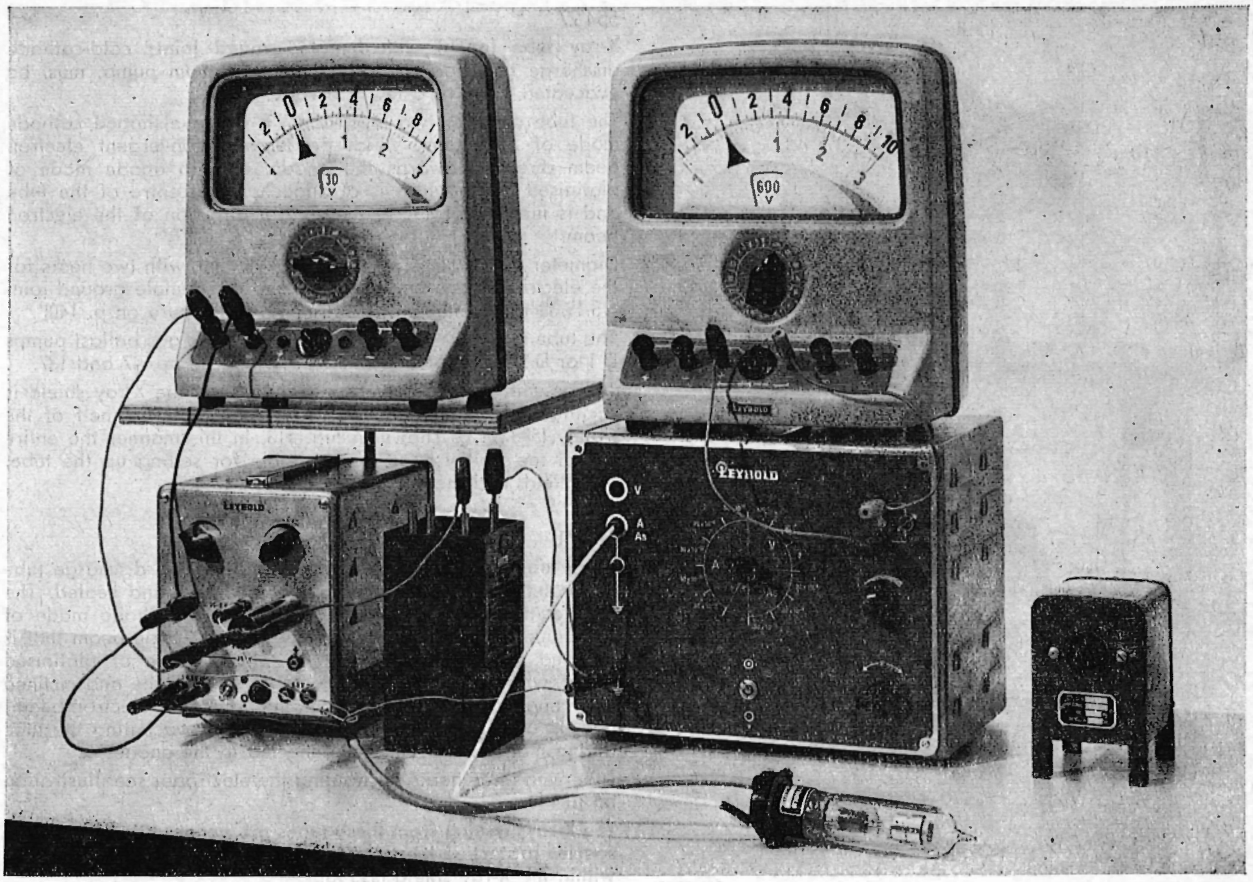


Fig. 112 Experimental arrangement for the Franck-Hertz experiment. PH 2064

Apparatus required:

1 Franck-Hertz tube	555 80
1 Power supply	522 35/33
1 Resistor, 100 kΩ	536 25
either:	
1 Meter, f.s.d. 300 µA, 60 mV, e.g.:	
Demonstration multirange meter	531 86
or:	
Demonstration millivolt-microammeter	531 87
and:	
1 Voltmeter for 30 V, int.res. >10 kΩ, e.g.	
Demonstration multirange meter	531 86
or:	
Twin moving-coil instrument	442 73
2 Range control boxes	442 74
1 Measuring amplifier	532 01
1 Accumulator e.g.	522 70
For heating at 220 V A.C. mains voltage:	
1 Electric oven 220 V A.C.	555 81
1 Rheostat, 320 Ω	537 23
or at 110 V A.C. mains voltage:	
1 Electric oven, 110 V A.C.	555 82
1 Rheostat, 110 Ω	537 24
1 A.C. voltmeter for up to 100 V*), e.g.	
Universal moving-coil instrument	531 55 or 56

*) If necessary, one of the multirange meters mentioned above can temporarily be used here while setting up the oven.

6. Generation of X-rays

The treatment of X-rays in teaching is particularly desirable for the following reasons:

It is of great importance for the understanding of the image of the structure of matter formed in the pupils' minds.

The medical and technical applications of this radiation are nowadays very widespread.

Lastly, however, this gives a possibility of experimentally deriving the much-discussed problems of radiological protection and the definitions, methods of measurement, and protective measures.

For these reasons we have devoted much study to the experimental techniques when working with X-rays, and are, therefore, in a position to suggest experiments and supply apparatus in which all hazards to teacher and pupils are excluded. The limit we have adopted is to restrict the dose received during one year from work with radioactive matter or X-rays to 2–3 milli-roentgen; this value corresponds to approx. 1/50 of the dose normally received during this time by cosmic and background radiation.

A detailed presentation of all the relevant problems will be found in the paper by Dr. K. Hecht, "Dosimetrie und Strahlenschutz im Unterricht" (available in English in four parts: "School Health Physics", "Suggestions for class room experiments with X-ray and discharge tubes", "Suggestions for class room experiments with radioactive sources", and "Suggestions for class room experiments with the shielded laboratory source of neutrons"), which we shall be pleased to supply free of charge on request.

Here, we can only point out the following rules, which it is essential to follow:

1. X-ray tubes may only be operated inside the shielding box covered with a 1 mm thick lead layer and
2. observations may only be made with a phosphorescent screen covered with lead glass.
3. No parts of the human body, including the hands, may be irradiated.
4. The lecturer must also keep within the protective zone of the shield.
5. The lecturer should check the dose received by him with a pocket dosimeter and keep a record of the dosimeter readings.

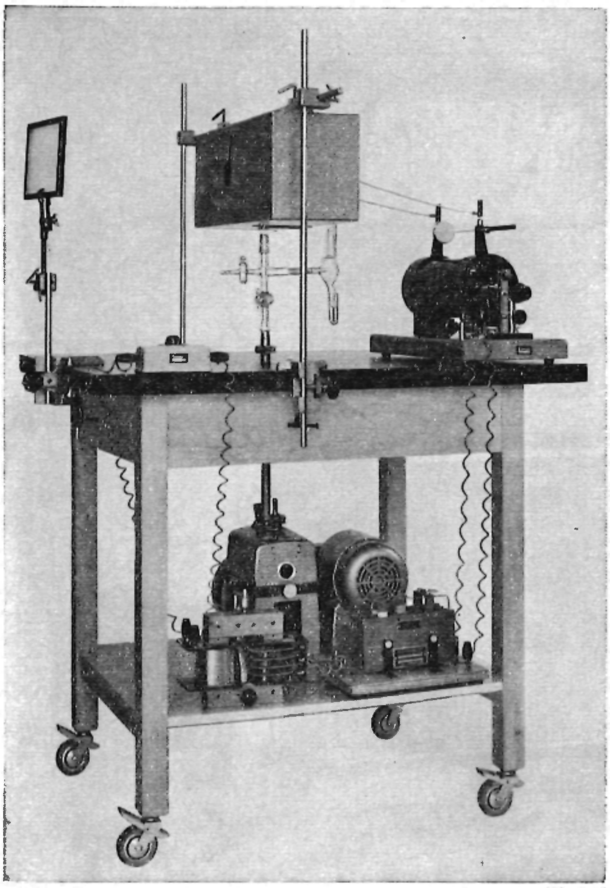
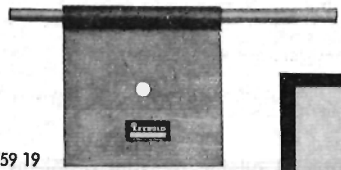
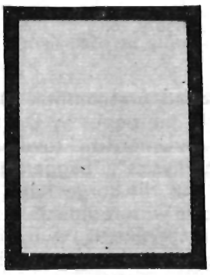
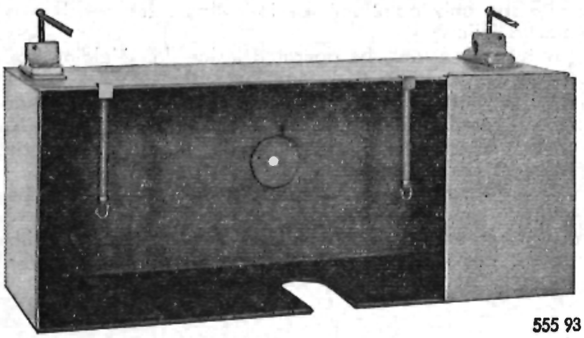


Fig. 113 **Experimental arrangements for generating X-rays,** consisting of: Trolley (598 10), gas ballast pump D 2 (110 12 S), lengthened intake port (379 20), adaptor (554 00), vacuoscope C (160 23), X-ray tube (554 27), X-ray shield (555 93), phosphorescent screen on lead glass backing (555 92), induction coil (521 11), demountable demonstration transformer (562 11/12/14 or 13/18), dry rectifier (523 72), stands and connecting leads.


559 19


555 92


555 93

554 27

X-ray tube (open) with female ground joint; cold-cathode discharge tube for operation with a vacuum pump, must be evacuated down to a few $^1/_{100}$ Torr.

The tube contains two electrodes: a concave-shaped cathode made of aluminium, which produces a convergent electron beam directed towards the anode, and an anode made of platinised nickel which is arranged at the centre of the tube and is inclined at 45° to the central direction of the electron beam.

Diameter of the glass bulb approx. 100 mm, with two necks for the electrodes, one earthing ring and one female ground joint NS 19/38 for connection to the pump (see figure on p. 140)

The tube may be evacuated by means of the gas ballast pumps D 1 or D 2 in the arrangement described on pp. 47 and 137.

The assembly on the pump with the use of the X-ray shield is facilitated by arranging the pump on the lower shelf of the trolley (598 10) as shown in Fig. 113. In this manner the entire top of the trolley becomes available for setting up the tube, the shield, and the source of voltage.

555 71

X-ray tube (sealed), dia. 100 mm; cold-cathode discharge tube evacuated to a pressure of a few $^1/_{100}$ Torr and sealed. The tube contains three electrodes: a concave cathode made of aluminium, which produces a convergent electron beam that is directed towards the anode; an anode made of platinised nickel, which is arranged at the centre of the tube and inclined at an angle of 45° to the central direction of the electron beam; and an auxiliary anode that is needed in evacuating the tube during manufacture, and is connected to the anode.

Tube with three necks for holding the electrode; see illustration on p. 140.

The X-rays issuing from these tubes are penetrating and require special protective measures. The tubes may only be operated within the X-ray shield (555 93).

As source of voltage we recommend induction coil (521 11).

555 92

Phosphorescent screen on lead glass backing, for detecting X-rays and studying their penetration properties. The shielding effect of the lead glass corresponds to that of a lead plate of 1 to 1.5 mm thickness. The relatively soft X-rays which are produced during the experiments with our X-ray tubes are therefore almost completely absorbed; 13×18 cm^2 in size, with zinc-cadmium sulphide coating and an opaque coating to exclude visible light on the back.

555 93

X-ray shield, for operating X-ray tubes 554 27 and 555 71; this shield should always be used when working with these tubes. With correct use it will safely shield teacher and class from X-rays, without unduly restricting the facilities for observation. 50×18×20 cm^3 in size, made of sheet-iron; lined inside with 1 mm thick seamless lead layer. The front side has an opening of 5 cm diameter that can be covered with a lid, this lid in turn having an opening of 1 cm diameter. The rear is $^1/_3$ covered; the bottom has an opening for introducing the vacuum line. With two insulators for supplying high tension, and clamping devices for mounting on stands. Weight: approx. 11 kp (kg wt).

559 19

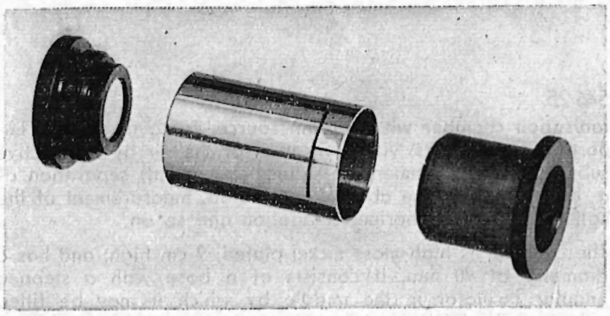
Lead diaphragm, for producing a narrow beam of X-rays, mainly for experiments on X-ray dosimetry. Lead foil, 12×12 cm^2 in size, 1 mm thick, with a circular hole of 10 mm diameter, mounted on a stand rod of 25 cm length and 12 mm diameter.

The lead diaphragm is generally mounted on a stand in front of the exit opening of the X-ray shield (555 93).

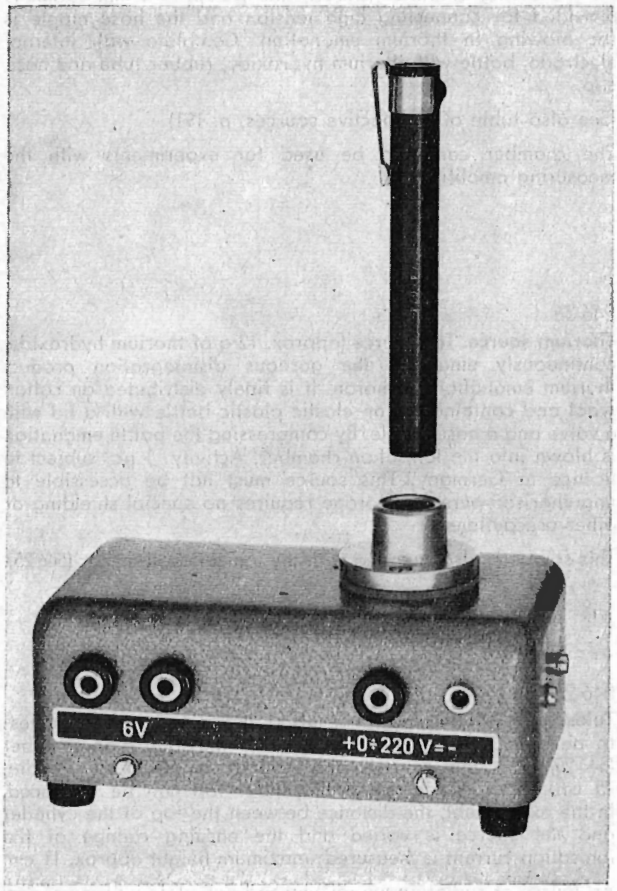
7. Detection and measurement of radioactivity

Several methods of measurement are available for the experimental introduction to nuclear physics in teaching. These processes, originally designed as simple experiments for detecting nuclear radiation, have meanwhile been developed into powerful measuring techniques in modern nuclear radiation technology.

It is a good thing to go back to the simple experiments, because in their case the basic underlying facts come out with greater clearness. Suitable means are photographic plates, the spinthariscope, the electrometer, the ionisation chamber, the point (Geiger) counter, the Geiger-Müller counter and the cloud chamber. With these detectors radioactive matter and its decay products can be detected, and their activities determined, with almost the same sensitivity as with more modern nuclear physics measuring instruments, though, of course, not quite so conveniently.



559 51



546 60
546 61

7.a, Scintillation

The scintillation of fluorescent crystals was one of the earliest methods used for detecting radioactive substances.

This method later on gained great importance and led to the construction of extremely efficient scintillation counters. The principle of a scintillation counter can be shown by means of a spinthariscope, an instrument containing a very weak radioactive source, a fluorescent screen, and an eyepiece. In a sufficiently darkened room, the flashes of light on the screen as radioactive decay products impinge on it can be observed after sufficient adaptation of the eye to the feeble brightness of the phenomenon.

559 51

Spinthariscope, for detecting radioactive radiation by means of the light flashes on a luminous screen. The instrument consists of a cylindrical metal tube containing in a screw top a fluorescent screen in which a very weak radioactive source is embedded. At the other end a tube with an eyepiece (focal length approx. 2.5 cm) is inserted. Overall length approx. 4 cm.

Since the radioactive source has an activity of less than 0.01 μc, it is not subject to licence in the Federal Republic of Germany. However, unsupervised handling by children should be avoided. Special radiological protection in storage is not necessary.

7.b, Pocket dosimeter

546 60

Pocket dosimeter, for determining X-ray and γ-ray doses. This instrument is intended as a personal protection against inadvertent exposure to excessive radiation doses when handling X-ray tubes and radioactive sources. We recommend all experimenting teachers to carry this instrument, in operational condition, with them all the time and to keep a written record of the values read. In this manner damage resulting from unnoticed occupational doses, even over long periods of time, can be avoided. The instrument is, moreover, suitable for measurements with radioactive sources and cathode ray tubes of all kind.

The range is 200 mr, which can be read on a scale containing 40 scale divisions with an accuracy of ±6% of the full scale deflection.

The self-discharge within 24 hours is less than 2% of f.s.d. The instrument is of the shape and size of a fountain pen and contains an ionisation chamber, a glass fibre electroscope with scale, and a reading microscope. It is charged to a predetermined voltage with the help of a charging unit. When exposed to ionisation radiation, its discharge is proportional to the dose received. The scale is divided in units of 5 mr. For charging, a special charging unit (546 61) is required which is equipped with a special socket. The charging contact of the dosimeter becomes accessible only after it has been completely pressed into the special charging socket, thus preventing involuntary discharge.

546 61

Charging unit for the pocket dosimeter, with special socket which will only make a contact when the dosimeter is completely pressed in, in this manner preventing an inadvertent discharge of the dosimeter. The indicating fibre of the dosimeter is adjusted to the beginning of the scale by varying the supplied voltage, at the same time viewing the fibre through the eyepiece. During the reading, the scale is illuminated by a lamp that is provided inside the charging unit.

In case, $7 \times 12 \times 5$ cm³ in size, with two pairs of sockets for connecting a charging voltage of approx. 220 V D.C. and a lamp voltage of 6 V. Complete without source of voltage; we recommend using the power supply 522 35/33.

7.c, Wulf electroscope

The Wulf electroscope is eminently suitable for introductory observations and measurements in the field of radioactivity. In the case of all experiments with the Wulf electroscope*), the following ancillary apparatus will be found useful:

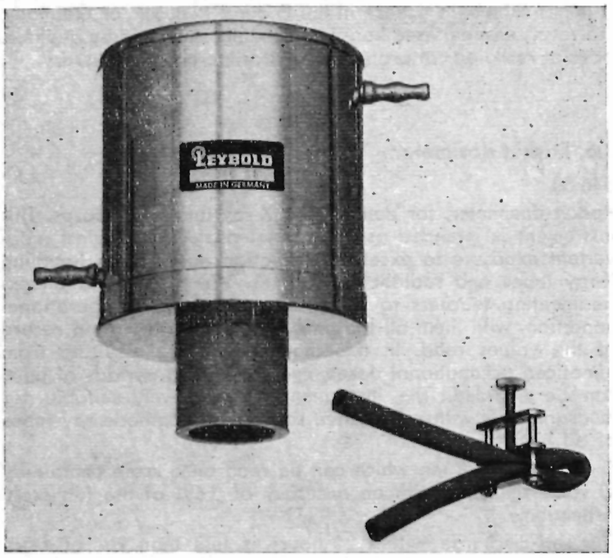
Wulf electroscope	546 00
Projection attachment	546 02
Stand base, length of sides 20 cm	300 02
Resistor, 100 MΩ	536 22
For illumination:	
Lamp house	450 60
Lamp, 6 V, 30 W	450 51
Single-lens condenser	460 17
As source of voltage:	
High-tension power supply	522 37
or:	
Van de Graaff generator	541 70
Driving electric motor, 220 V	563 35
or 110 V	563 36
High-tension capacitor	538 82
For voltage reading:	
Electroscope	540 09
or:	
High-tension voltmeter, 1 kV	540 38
High-tension voltmeter, 4 kV	540 39

In contrast to electronic amplifiers and recording devices, experiments with this equipment are based on already known facts and are thus a sound introduction to the use of modern scaling apparatus. Starting with the ionisation current in an ionisation chamber, the properties of the radiations emitted by radioactive sources and the modes of action of point counters and Geiger-Müller counters can be shown. For these measurements the "pulse method" described on p. 132 for measuring small currents is used.

For time measurements during the various experiments we recommend using:

Large electric stop-clock	313 02/04/08
or	
Stop-clock with clockwork	313 05
or	
Stop-watch	313 06

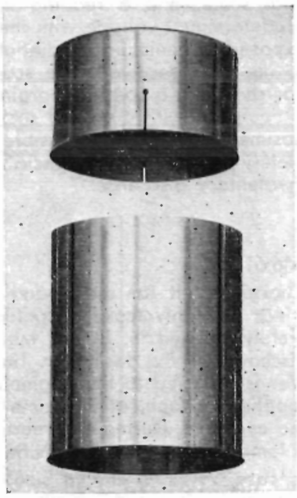
Some of the apparatus listed below may also be used with the electronic scaling units (see p. 185).



546 25

LEYBOLD
546 36
MADE IN GERMANY
Th 0,5 → 1μc

546 36
This source is also supplied with the ionisation chamber (546 25).



546 27

546 25

Ionisation chamber with thorium source, for a number of important experiments, viz.: ionisation of the air by radioactive substances, measurement of saturation current, separation of α- and β-rays by the absorption method, measurement of the half-life period of thorium emanation and so on.

The chamber is high-gloss nickel-plated, 9 cm high, and has a diameter of 90 mm. It consists of a base with a stepped annular insulator in the middle by which it may be fitted either on the Wulf electroscope or on the shielded cable of the measuring amplifier (532 01), and a top. A 4 mm socket is provided for connecting high tension and the hose nipple is for blowing in thorium emanation. Complete with internal electrode, bottle with thorium hydroxide, rubber tube and hose clip.

(See also table of radioactive sources, p. 191)

The chamber can also be used for experiments with the measuring amplifier.

546 36

Thorium source. The source (approx. 12 g of thorium hydroxide) continuously emanates the gaseous disintegration product thorium emanation or thoron. It is finely distributed on cotton wool and contained in an elastic plastic bottle with a lid with a valve and a hose nipple. By compressing the bottle emanation is blown into the ionisation chamber. Activity: 1 μc; subject to licence in Germany. This source must not be accessible to unauthorised persons. Storage requires no special shielding or other precautions.

This source is also supplied with the ionisation chamber (546 25).

546 27

Telescopic cylinder, for measuring the range of α-particles; to be used together with the base of the ionisation chamber (546 25). The item consists of a cylindrical metal sleeve, dia. 75 cm, within which a metal cylinder top can be displaced. In the experiment, the distance between the top of the cylinder and the source is varied and the ensuing change of the ionisation current is measured; maximum height approx. 11 cm.

As source of radiation we recommend our plate with protected radioactive source (546 44).

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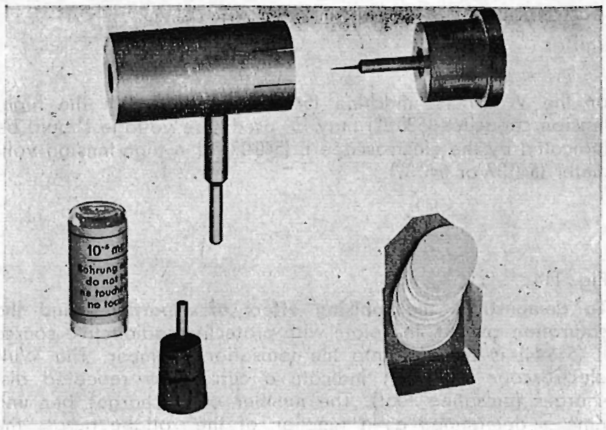
*) For details and illustrations, see p. 132



546 28

546 28

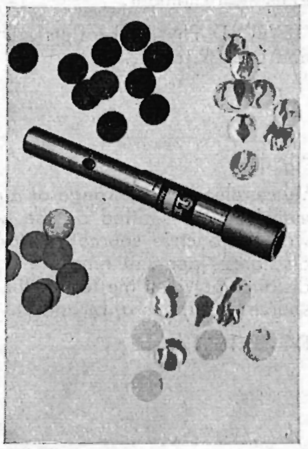
Point counter (Geiger counter), for a particularly easily comprehended introduction to the operation of a counter. This counter will detect individual α-particles from a very weak source. The open counter can be taken apart and consists of a metal cylinder with plug and an artificial resin insulator. The insulator carries a needle that is connected to a 4 mm socket. For the experiment, the point counter is fitted onto the Wulf electroscope; it may also be connected to an amplifier by means of the adaptor (546 38) (see p. 187).
Length approx. 5 cm, complete with one set of thin aluminium foils for preventing the entrance of dust into the window, and a radium source of 10^{-3} μc activity which is not subject to licence in the Federal Republic of Germany. However, unsupervised use by youthful persons should be avoided. Radiological protection in storage is unnecessary.

LEYBOLD
546 44
Ra 5-10 µc
MADE IN GERMANY

546 44

546 44

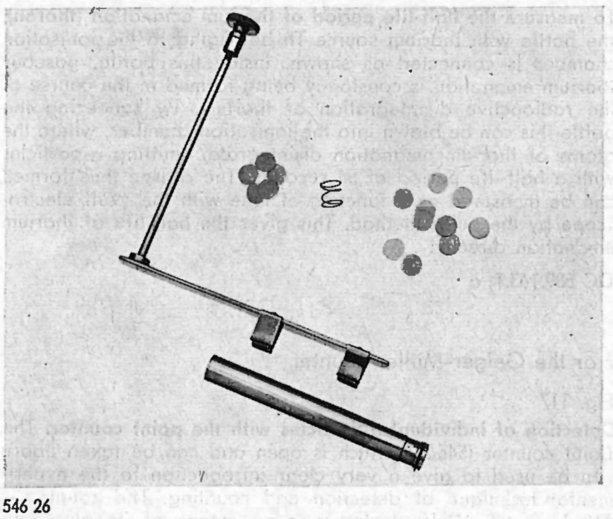
Plate with protected radioactive source. Radium source for studying the properties of α-, β-, and γ-rays. Activity approx. 5–10 μc. This source was designed with particular care for safe use in teaching.
The radium is rolled into a thin noble-metal foil, reducing the leakage rate of emanation to less than 1% of the equilibrium value, which is attached to the plate. The plate is stored in a glass vessei where its presence can be checked at a glance, while the glass shields off α- and β-rays and acts as a distance shield for the hand holding the source. For technical data see the table: Radioactive sources, p. 191.
Plate, dia. 10 mm, with 4 mm plug; in glass jar with screw top. The source is subject to licence in the Federal Republic of Germany. It should not be accessible to unauthorised persons. Radiological protection measures in storage are not necessary.



559 18

559 18

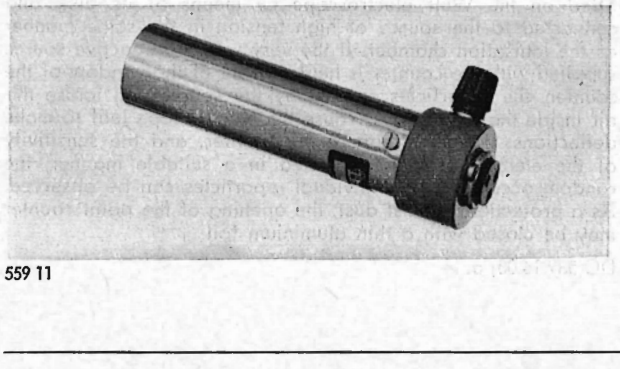
Holder with absorber foils, for inserting radioactive sources, with exchangeable absorber foils. The holder is approx. 10 cm long and has a central hole for inserting the sources, and a cap with hole for inserting the absorber foils. A lateral hole, dia. 4 mm, can be used for calibration or when using the device as a radioactive probe. Complete with brass ring for limiting the beam, and the following absorber foils: 10 aluminimum foils of each of the following thicknesses: 0.01, 0.1, and 1 mm, and 10 lead discs, each 1 mm thick.



546 26

546 26

Collimator tube, for collimating the β-rays issuing from radium source 546 44. The device is particularly suitable for demonstrating the deflection of β-rays in a magnetic field. The required field is produced by an electromagnet. For details see pp. 185 and 187.



559 11

559 11

Socket for Geiger-Müller tube, for operating counters on the Wulf electroscope. The socket is mounted on a metal tube, the lower, slotted end of which is fitted on the Wulf electroscope. The tube contains a 10^9 Ω resistor that acts as the load resistor of the counter.
The socket will take either of the counters 559 10 and 559 14.

559 10

Geiger-Müller tube for counting β (and some γ) -rays.
For detailed description see p. 186.

559 14

End-window counter for counting α, β (and some γ) -rays.
For detailed description see p. 186.

Nuclear physics experiments incorporating the Wulf electroscope

Experiments with the Wulf electroscope and the Ionisation chamber

The ionisation chamber (546 25) is mounted on the Wulf electroscope (546 00) and connected to a source of high tension H via a safety resistor W (100 MΩ, 536 22). Instead of the high-tension power supply (522 37) shown in the illustrations, an arrangement incorporating the van de Graaff generator (541 70) or the Wimshurst machine (541 65) together with the high-tension capacitor (538 82) may be used. The voltage should be indicated by the electroscope E (540 09) or a high-tension voltmeter (540 37 or 540 39).

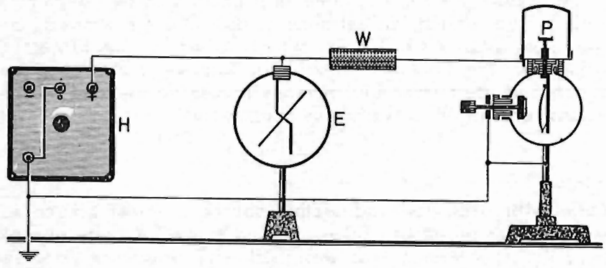


Fig. 114

Fig. 114

To demonstrate the ionising effect of α-particles and the saturation current, the plate with protected radioactive source P (546 44) is inserted into the ionisation chamber. The Wulf electroscope will then indicate a current by repeated discharges (pulsating leaf). The number of discharges per unit time is determined as a function of the voltage across the ionisation chamber.

"LEYBOLD Physics Leaflets", DC 539.163; b, DC 539.164.92; a, and DC 539.164.92; c.

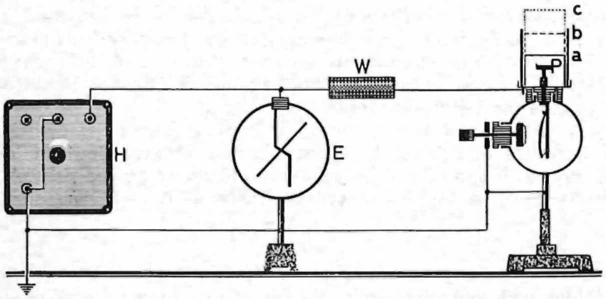


Fig. 115

Fig. 115

Measurement of the range of α-particles. The telescopic attachment (546 27) is fitted on the base of the ionisation chamber with radioactive source P (546 44) in position. The number of discharges per unit time are determined as a function of the distance between the top of the telescopic attachment, and the source. (Positions a, b, and c).

DC 539.163.2; a

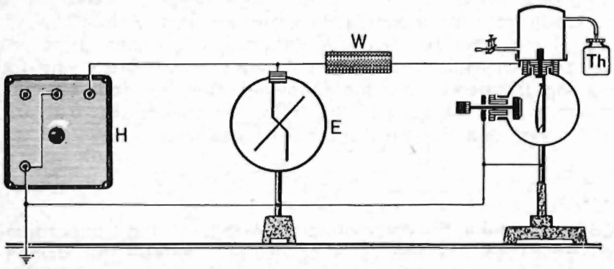


Fig. 116

Fig. 116

To measure the half-life period of thorium emanation (thoron), the bottle with thorium source Th belonging to the ionisation chamber is connected as shown. Inside this bottle, gaseous thorium emanation is constantly being formed in the course of the radioactive disintegration of thorium. By squeezing the bottle this can be blown into the ionisation chamber, where the atoms of thorium emanation disintegrate, emitting α-particles with a half-life period of 54 seconds. The charge thus formed can be measured as a function of time with the Wulf electroscope by the pulse method. This gives the half-life of thorium emanation directly.

DC 539.163.1; a

Experiments with the Wulf electroscope and the point counter or the Geiger-Müller counter

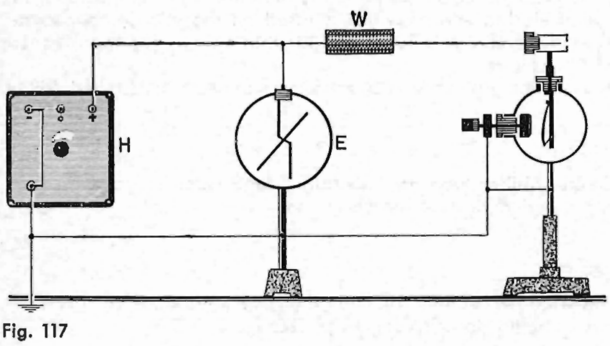


Fig. 117

Fig. 117

Detection of individual α-particles with the point counter. The point counter (546 28), which is open and can be taken apart, can be used to give a very clear introduction to the experimental technique of detection and counting. The counter is fitted on the Wulf electroscope by means of its plug and connected to the source of high tension in the same manner as the ionisation chamber. If the very weak radioactive source supplied with the counter is held in front of the window of the counter, the α-particles emitted by the source will ionise the air inside the counter and cause the electroscope leaf to make deflections. If the voltage at the counter, and the sensitivity of the electroscope, are adjusted in a suitable manner, the random occurrence of individual α-particles can be observed. As a protection against dust, the opening of the point counter may be closed with a thin aluminium foil.

DC 539.16.08; a.

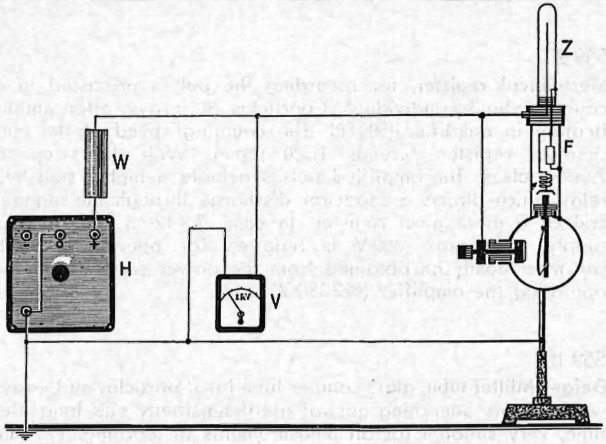


Fig. 118

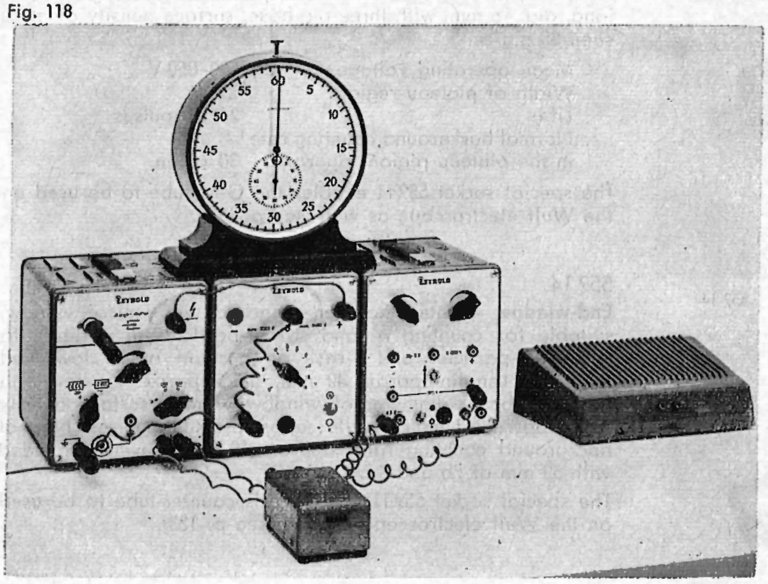


Fig. 119 PH 2066

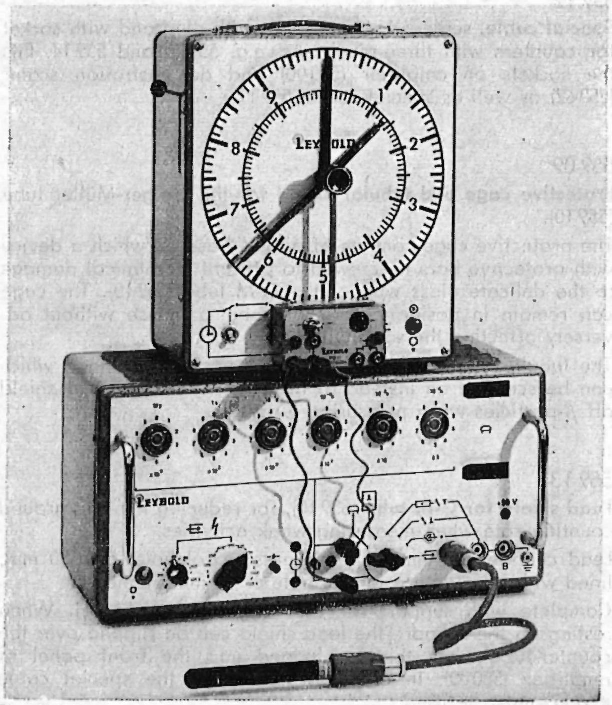


Fig. 120 PH 2067

Fig. 118

Detection of individual β- and γ-rays with a G-M counter. The Geiger-Müller tube (559 10) is mounted on the special socket F (559 11) which in turn is fitted on the Wulf electroscope. The voltage for operating the counter can be supplied by the high-tension power supply (522 37) and checked by means of the high-tension voltmeter (540 38), as it is important to maintain the voltage accurately at its correct value. For this experiment the Wulf electroscope can be rendered particularly sensitive by biassing the side-electrode, also with the high-tension power supply. The Wulf electroscope will then indicate every β- or γ-particle that becomes effective within the counter by a marked twitch of the leaf.

This arrangement may be used, for example, in the following experiments:

Determining the characteristic curve of a counter
Demonstration of the normal radiation background
Detection of β- and γ-rays from radioactive sources
Discrimination of β- and γ-rays by absorption measurements
Magnetic deflection of β-rays
Studies on frequency distributions

DC 539.16.08; b, DC 537.533.335; b, DC 539.16.08; d, DC 539.162.088; a

7.d, Electronic scalers

A more thorough treatment of nuclear physics necessitates the use of electronic devices for amplification of the counter-tube pulses.

In the following, we describe two pieces of apparatus that are suitable for this purpose; the two have this in common that the equipment needed in order to have satisfactory scaling results can also be used for numerous other experiments. When seen from this point of view, the purchase of one of the devices listed below is more economical than that of a specialised unit which is simply and only suitable for use with counter-tubes.

Fig. 119 **G-M tube amplifier** assembly with speaker and mechanical register.

This arrangement is suitable for quantitative determinations at pulse rates of up to 1,500 p.p.m. and consists of the following parts:

Amplifier	580 00*)
Power supply	522 35/33
High-tension power supply	522 37
Speaker	580 05
or	
Mechanical register	559 20

*) For a detailed description, see the Chapter "Electronics" p. 162

The G-M tube amplifier assembly represented in Fig. 119 can be modified to constitute a ratemeter for continuous reading of the mean value of the count-rate. For this purpose, a moving-coil instrument damped by a capacitor is connected to the amplifier output in the place of the mechanical register. We recommend:

Capacitor 2,500 µF	538 31
Demonstration multirange meter	531 86
or	
Demonstration millivolt-microammeter .	531 87
or	
Twin moving-coil instrument suitable for projection, and	442 73
2 Range control boxes for same	442 74

Fig. 120

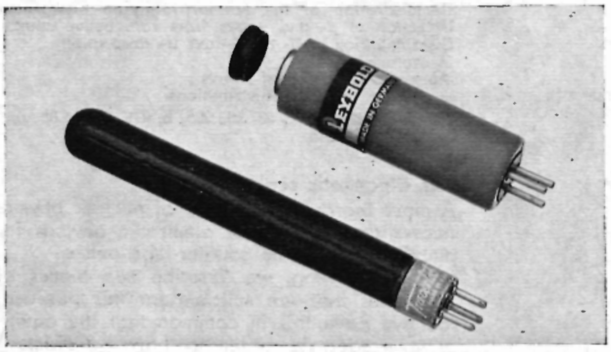
Demonstration scaler with provision for pre-setting the counting period.

The demonstration scaler (559 62) is suitable for all counting problems likely to occur in teaching. The assembly and operation of this unit are time-saving and simple, because all necessary circuit elements are built-in. The demonstration scaler has 6 fully electronic decades and its input resolution is 50 µs, making it suitable for counting rates of up to 20,000 counts/s. A source of high tension yielding approx. 1,125 V, and a coarse and fine adjustment knob for it are built in. For a detailed description of the unit, see Chapter "Electronics", p. 164.

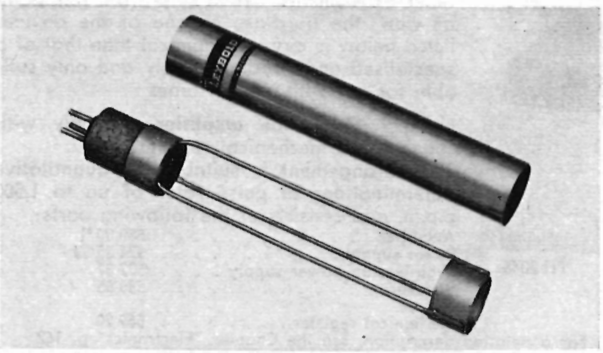
For the assembly as shown in the figure, the following pieces of apparatus are additionally required:

Large electric stop-clock	313 02/04/08
Pre-set time switch for same	559 72
Geiger-Müller tube	559 10
Special cable for connecting same . .	559 12

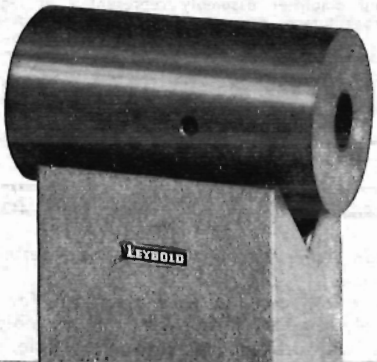
559 20



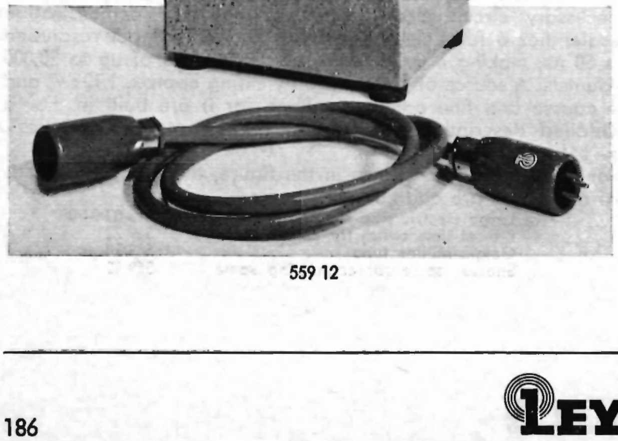
559 10 559 14



559 09



559 13



559 12

559 20

Mechanical register, for recording the pulses produced in a counter-tube by individual β-particles or γ-rays, after amplification in amplifier (580 00). The counting speed of the mechanical register exceeds 1,500 p.p.m. With digits up to 99,999 pulses. The amplified pulses actuate a highly sensitive relay which directs a capacitor discharge through the magnet coil of a mechanical register. In case, $7\times12\times5$ cm^3. A D.C. supply of approx. 300 V is required for operation, which can most easily be obtained from the power supply used for operating the amplifier (522 35/33).

559 10

Geiger-Müller tube, glass counter-tube for β-particles and γ-rays with organic quenching gas, of great sensitivity and long lifetime, very suitable for all measurements in teaching. 125 mm long, dia. 16 mm, with three-pin base, surface density of glass shell 30 mg/cm^2.

Mean operating voltage:	780–850 V
Width of plateau region:	150 V
Life:	2×10^8 pulses
Normal background counting rate in the plateau region: approx.	30 p.p.m.

The special socket 559 11 enables the G-M tube to be used on the Wulf electroscope as well (see p. 183).

559 14

End-window counter, halogen-quenched, with mica window, suitable for counting α- and soft β-particles in addition to normal β-particles and γ-rays on account of its low wall thickness. Length approx. 80 mm, dia. approx. 15 mm, with three-pin base; diameter of window: 9 mm; surface density of window: 2–3 mg/cm^2; life: approx. 5×10^{10} pulses. Normal background counting rate: approx. 10 p.p.m. (when shielded with 50 mm of Pb and 3 mm of Al).

The special socket 559 11 enables this counter-tube to be used on the Wulf electroscope as well (see p. 183).

559 12

Special cable, screened, 60 cm long, with plug and with socket for counters with three-pin bases, e.g. 559 10 and 559 14. Fits the sockets on amplifier (580 00) and demonstration scaler (559 62) as well as special socket 559 11.

559 09

Protective cage and tubular shield for the Geiger-Müller tube (559 10).

The protective cage consists of a G-M base on which a device with protective bars is screwed to prevent mechanical damage to the delicate glass wall of the G-M tube (559 10). The cage can remain in position while the tube is in use without adversely affecting the sensitivity of the tube.

The tubular shield (1 mm wall thickness, 130 mm long), which can be screwed on instead of the cage, is designed to shield off β-particles when measuring γ-rays.

559 13

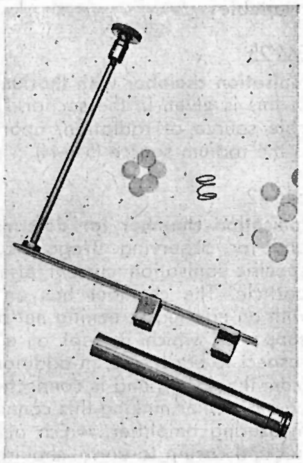
Lead shield for G-M tube (559 10), for reducing the background counting rate when measuring weak activities.

Lead cylinder, 35 mm wall thickness; axial hole, dia. 30 mm, lined with iron; with a lateral hole of 10 mm diameter.

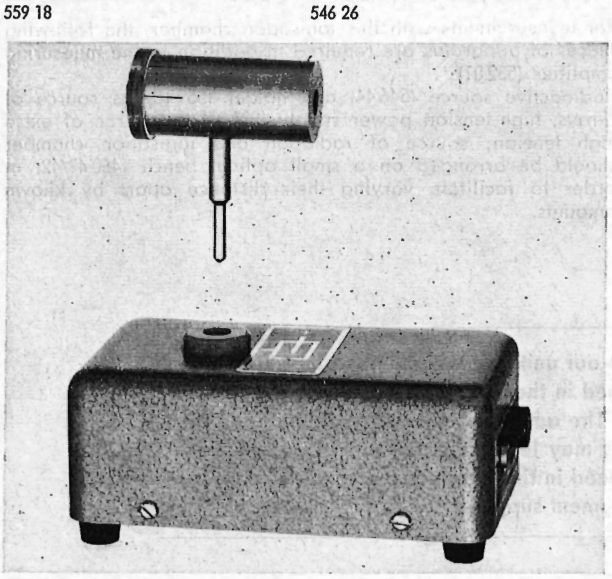
Complete with support for use with axis horizontal. When resting on the support, the lead shield can be slipped over the counter-tube when this is plugged into the front panel of amplifier (580 00). In other arrangements, the special cable (559 12) must be used.

559 16

559 18



546 26



546 28 (top) and 546 38 (bottom)

559 16

Calibrating vessel, for calibrating the counter-tube (559 10). Cylindrical sheet-metal container, dia. 100 mm, 18 cm high, with one concentrically arranged inner tube into which a counter-tube (559 10) fitted with special cable (559 12) may be introduced. If the annular space between the two metal cylinders is filled with potassium sulphate up to the mark, the γ-intensity prevailing in the inner tube is equivalent to a Ra-γ-radiation of 26 µr/h.

After deduction of the background counting rate – for its determination the annular space between the two metal cylinders must be filled with sodium sulphate – the count-rate of the counter can be calibrated in units of dose-rate; without chemical agents.

559 18

Holder with absorber foils, for inserting radioactive sources, with exchangeable absorber foils. The holder is approx. 10 cm long and has a central hole for inserting the sources, and a cap with hole for inserting the absorber foils. A lateral hole, dia. 4 mm, can be used for calibration or when using the device as a radioactive probe. Complete with brass ring for limiting the beam, and the following absorber foils: 10 aluminium foils of each of the following thicknesses: 0.01, 0.1, and 1 mm, and 10 lead discs, each 1 mm thick.

546 26

Collimator tube, for collimating the β-radiation issuing from the radium source 546 44. The source can be inserted into the sprung end of the tube. Complete with: 5 aluminium absorber foils, 0.2 mm; 10 aluminium absorber foils, 0.5 mm thick, and one holder with spring clips. The apparatus is particularly suitable for demonstrating the deflection of β-rays by a magnetic field. The field required can be produced by means of an electromagnet (e.g. 562 11, 2×562 13 and 560 31). The holder can be inserted into this assembly.

As detector, the G-M tube (559 10) with suitable recording equipment should be used.

546 28

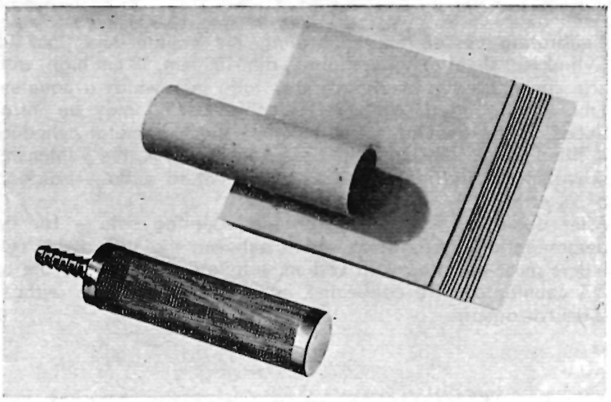
Point counter, designed by Geiger, for a particularly easily understood introduction to the construction of counter-tubes. Individual α-particles from weak sources can be detected with it. The open counter can be taken apart and consists of a metal cylinder with a plug and a synthetic resin insulator. The insulator is provided with a needle which is connected to a 4 mm socket.

For the experiment, the Geiger counter is plugged into the Wulf electroscope or the adaptor (546 38).

Length approx. 5 cm, complete with a set of thin aluminium foils for preventing dust from entering the window, and a radium source of 10^{-3} µc activity which is not subject to licence in the Federal Republic of Germany. However, unsupervised use by juveniles should be avoided. Special radiological protection measures during storage are not necessary.

546 38

Adaptor for the point counter, for matching the point counter to amplifier (580 00); in case, approx. 7×12×5 cm³ in size, with sockets for the point counter and for connection to the high-tension power supply and the amplifier input.



546 40 546 41

546 40

Suction tube for use with filter, device for collecting radioactive particles suspended in the atmosphere by drawing air through a filter using a vacuum pump. After several hours of pumping the daughter products of radium and thorium will collect on the filter. The activity of these substances can be detected with a G-M tube (559 10) and the fall of activity can be studied. Tube made of wire gauze, approx. 12 cm long, dia. 35 mm; with hose nipple for connection to a vacuum pump.

Additionally required: Filter sheets (546 41).

546 41

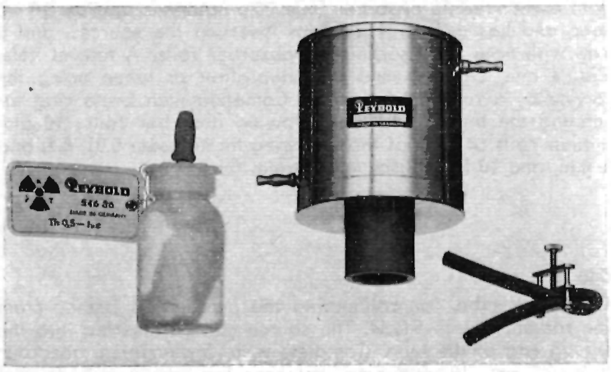
Filter sheets, set of 10, for use with the suction tube.

7.e, Measuring amplifier

On account of its high current sensitivity, the **measuring amplifier** (532 10) is suitable for the detection of ionisation currents produced in ionisation chambers. This amplifier can be used to determine the current-voltage characteristic of an ionisation chamber and to determine ranges of particles, absorption coefficients and half-life periods.

A detailed description of the measuring amplifier will be found in the chapter "Measuring instruments", p. 124.

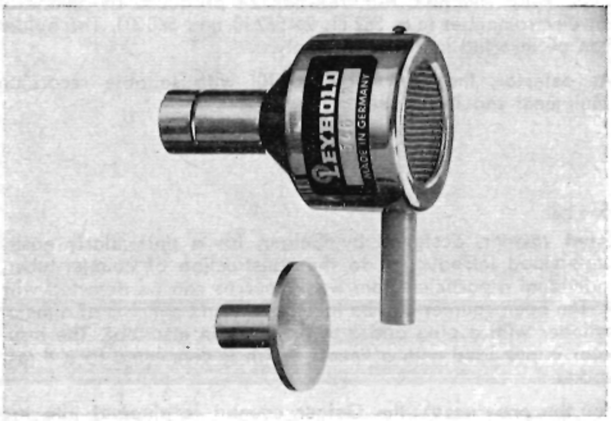
For measuring ionisation currents two ionisation chambers are available:



546 25

546 25

Ionisation chamber with thorium source. A detailed description of this is given in the section "Atomic Physics", p. 182. A suitable source of radiation, apart from the thorium emanation, is the radium source (546 44).



546 42

546 42

Ionisation chamber for determining the range of α-particles, and for observing Bragg's curve, i.e. the increase of the specific ionisation current at the end of the track of an α-particle. The chamber has an opening of 26 mm diameter, with an earthed screening net behind which an insulated net is supported which is kept at a potential of 1 . . . 1.5 kV with respect to earth and, in addition, a collector which is insulated from the casing and is connected to the input of the measuring amplifier. For making this connection, the shielded cable of the measuring amplifier, which also connects the screening wire net and casing to earth, should be used.

For measurements with this ionisation chamber, the following pieces of apparatus are required in addition to the measuring amplifier (532 01):
Radioactive source (546 44) and holder (559 18) as source of α-rays, high-tension power supply (522 37) as source of extra high tension; source of radiation and ionisation chamber should be arranged on a small optical bench (460 41/42) in order to facilitate varying their distance apart by known amounts.

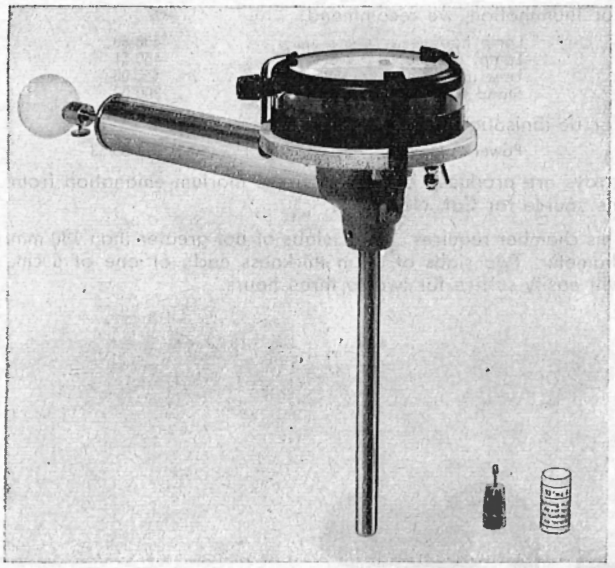
It is the aim and policy of our firm to design our units of equipment so that they are in line with the most recent knowledge gained in the field of physics and the latest methods applied in the science of teaching. The adoption of up-to-date methods of production and modifications to accessories may lead to variations in design. For this reason, the data and illustrations contained in this catalogue are not binding in all details for the design of the units of equipment supplied.

7.f, Cloud chambers

The cloud tracks produced by ionising events in cloud chambers convey an important and vidid impression of processes in nuclear physics, because they mark the paths of radioactive decay products which can thereby be directly observed. There are two kinds of cloud chambers, both of which are used in teaching.

In the expansion cloud chambers according to Wilson, a volume of air saturated with vapour is suddenly expanded, resulting in adiabatic cooling. This leads to a supersaturation of the vapour so that condensation takes place instantaneously if an ionising particle produces condensation nuclei in the form of ions. The result is a cloud track which can be observed visually or photographically if suitably illuminated. After each expansion, the chamber is sensitised for some 1/100 ths of a second, providing, so to speak, a snap-shot from the world of radioactivity.

In diffusion cloud chambers, on the other hand, the necessary supercooling is produced during the diffusion of vapour from a region of continuous evaporation to one of continuous condensation under the influence of a high temperature gradient. In a supersaturated layer above the condensation zone the chamber remains sensitised for a long period once a state of equilibrium has established itself. The random appearance and disappearance of the tracks due to particles from background or cosmic radiation can be observed for hours on a stretch. α-rays from traces of emanation or the secondary electrons produced by X-rays can also be observed.


559 57 559 59

559 57

Expansion cloud chamber designed by Schürholz (Wilson's cloud chamber). Simple and easily operated expansion cloud chamber suitable for observing the cloud tracks of α-particles. It consists of a firm base plate with a special attached hand pump providing a consistent and adjustable expansion ratio, and a stand rod for mounting it in a bench clamp (301 06). The suction port is at the centre of the chamber and is covered by a plate to prevent turbulence during the expansion. The chamber is closed by a detachable transparent plastic top.

Two 4 mm sockets are fitted for applying a de-ionising field. The chamber is charged with a mixture of alcohol and water. For producing the α-particles, a weak radium source is inserted.

Illuminating device, source of voltage, radium source and stands are not supplied with the chamber.

For illumination, we recommend:

Lamp house	450 60
Lamp, 6 V, 30 W	450 51
Single-lens condenser	460 17
Saddle base	300 11

For de-ionisation:

Power supply	522 35/33

For producing the α-particles:

Radium source for the expansion cloud chamber	559 59

559 59

Radium source for the expansion cloud chamber, activity less than 0.1 µc, sealed source, arranged inside a hollow cylinder provided with a needle. In addition to being used with the cloud chamber, it can also be used for experiments with the Wulf electroscope and for counting experiments.*)

The source is not subject to licence in the Federal Republic of Germany. However, unsupervised use by juveniles should be avoided. Radiological protection measures in storage are not necessary.

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*) For details see the table of radioactive sources on p. 191.

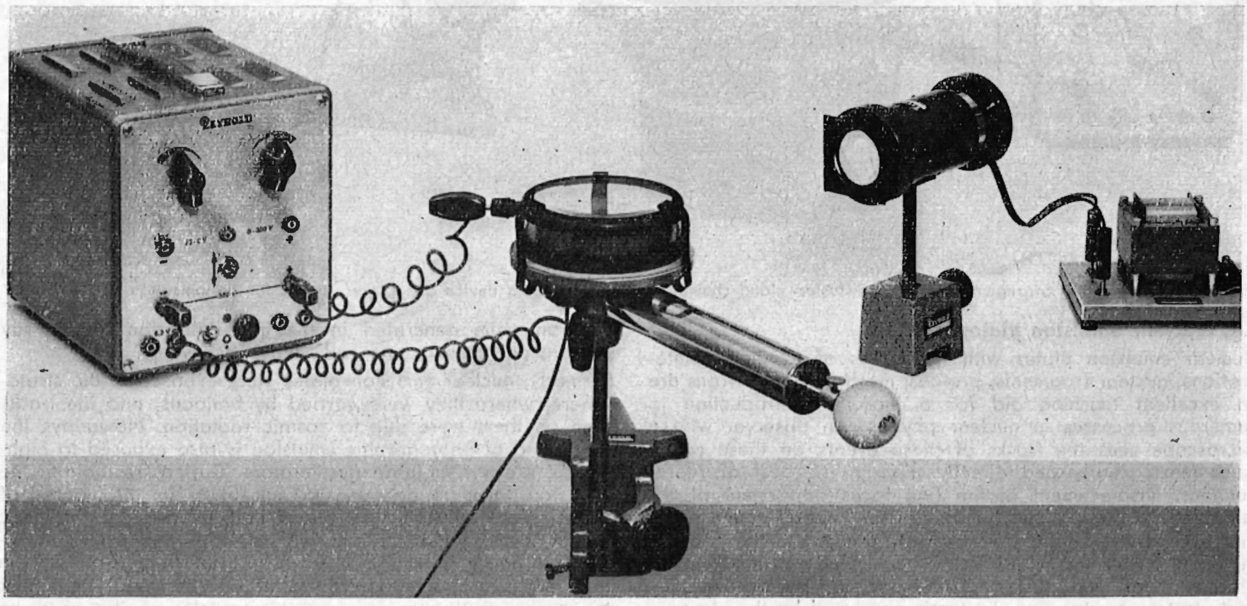
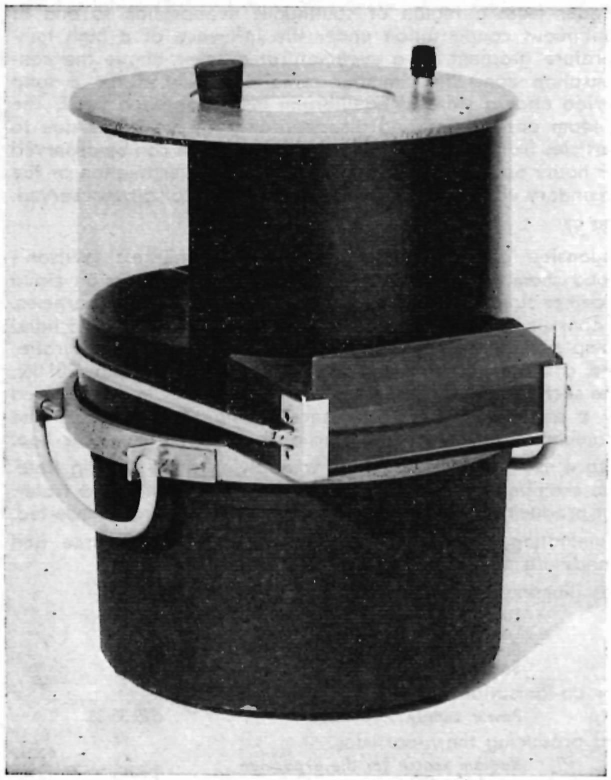


Fig. 121 Experimental arrangement with expansion cloud chamber, illuminating device and power supply (522 35) for de-ionisation. PH 2068



559 55

559 55

Diffusion cloud chamber, for observing the tracks of α- and β-particles and the secondary electrons produced by γ- and X-rays. The chamber is charged with a mixture of methyl alcohol and water and cooled with dry ice. After approx. 20 minutes, a stable state of diffusion with a supersaturated, sensitised zone has established itself.

The chamber consists of the following parts:

Lid with window and felt rim for soaking up the mixture, and with one opening for the admission of α-radiating substances,

Glass cylinder, diameter approx. 21 cm, about 1/3 of it varnished black, and dry ice trough made of heat-insulating material with sprung insert,

Light admission shaft, which prevents the formation of ice on the glass cylinder at the place where the light enters.

Illuminating device, source of voltage for de-ionisation and radioactive sources are not supplied with the chamber.

For illumination, we recommend:

Lamp house	450 60
Lamp, 6 V, 30 W	450 51
Lens in frame, f = 150 mm	460 08
Stand base, 20 cm length of side	300 02

For de-ionisation:

Power supply	522 35/33

α-rays are produced by means of the thorium emanation from the source for Cat. No. 546 36.

This chamber requires dry ice slabs of not greater than 180 mm diameter. Two slabs of 3 cm thickness each, or one of 6 cm, will easily suffice for two to three hours.

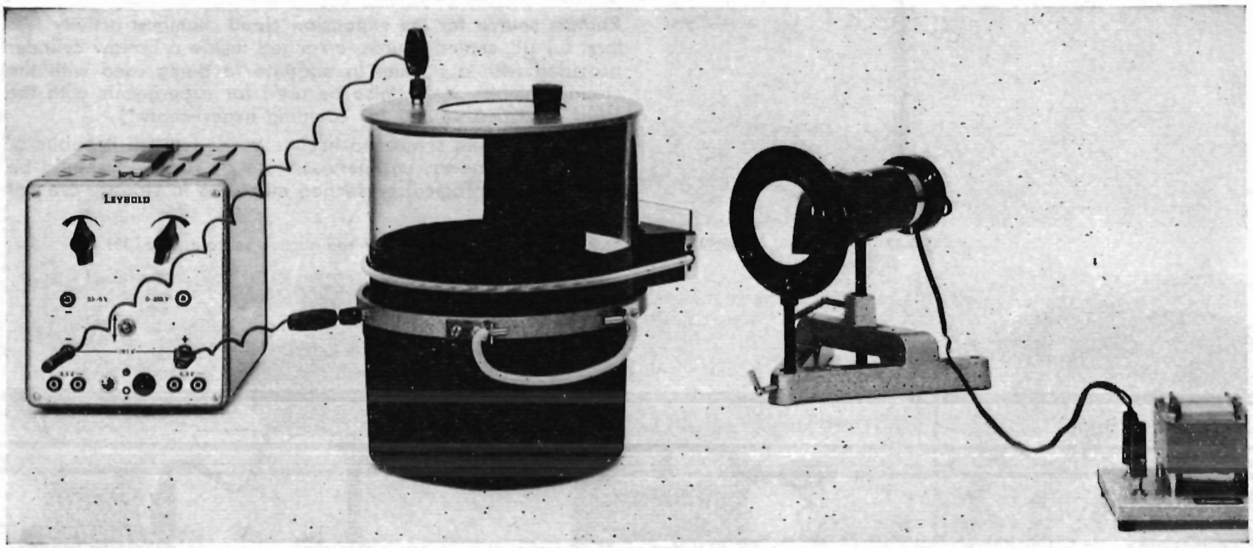


Fig. 122 Experimental arrangement for the diffusion cloud chamber with illuminating device and power supply for de-ionisation PH 2069

7.g, Nuclear emulsion plates

Nuclear emulsion plates with the tracks of nuclear disintegrations, nuclear fragments, protons, mesons and electrons are an excellent teaching aid for a thorough introduction to numerous processes in nuclear physics. An observer with a microscope sees the tracks of these events on these plates much more clearly and directly than in the best of reproductions. Displacement of the fine focus adjustment of the microscope clearly shows the spatial distribution of the tracks in the emulsion, which cannot be represented in plane drawings. The events that can be observed include, apart from the already mentioned nuclear disintegrations, proton-, meson-, and electron tracks, also the tracks produced by the electron-positron pairs generated in the materialisation of a γ-ray photon, and meson- and radioactive decays.

Formerly, nuclear emulsion plates were exposed in the stratosphere, where they were carried by balloons, and the tracks seen on them were due to cosmic radiation. Nowadays the same kind of photographic emulsion is also exposed to high-energy protons in large accelerators. During irradiation, the emulsion layer is approx. 0.6 mm thick. In the course of development it shrinks to about half its original thickness. In this layer, electrically charged particles and nuclear fragments produce silver "nuclei" which grow to approx. 0.7 μm thick silver grains in the course of development. They mark the paths of the various nuclear particles in the emulsion layer and their scattering and range. From the density of distribution of the silver grains inferences concerning the producing particles can be drawn.

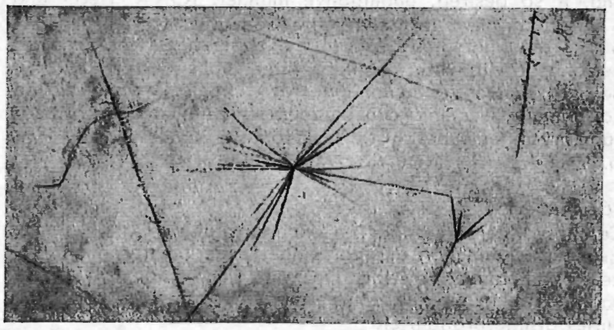


Fig. 123
Drawing representing a microscopic view of a nuclear emulsion plate

7.h, Radioactive sources

The following is a list of the radioactive sources contained in this catalogue. There is no need to stress that it is important to handle radioactive matter with great care and to mount radioactive sources in such a manner that both those conducting an experiment and others are well protected from harmful influences. However, it would likewise be wrong, for fear of these effects, to avoid experiments with radioactive sources altogether.

Physics teaching today cannot escape the task of allowing the pupils to discover at first-hand and by their own experimental observation the knowledge of the laws of physics that are necessary for the understanding of nuclear physics and its applications.

With proper choice of the equipment and suitable performance of the experiments it is possible to exclude all hazards to the pupils and to oneself and to keep the total exposure from such experiments within limits which are far below the level to which the human body is anyway exposed from background radiation. Even if this low level of exposure is postulated as upper limit of exposure, the experiments necessary for a proper treatment of the subject can be performed perfectly satisfactorily. In this context we would draw attention to the following booklet which we are pleased to send you on request:

Booklet, K. Hecht, **Dosimetrie und Strahlenschutz im Unterricht** (Available in English in four parts: "School Health Physics", "Suggestions for classroom experiments with X-ray and discharge tubes", "Suggestions for classroom experiments with radioactive sources" and "Suggestions for classroom experiments with the shielded laboratory source of neutrons"). This is a comprehensive collection of all the results of our experience in experimenting with X-ray and discharge tubes, with radioactive sources and the shielded laboratory source of neutrons. With introduction, additional interesting data and many illustrations, 56 pages.

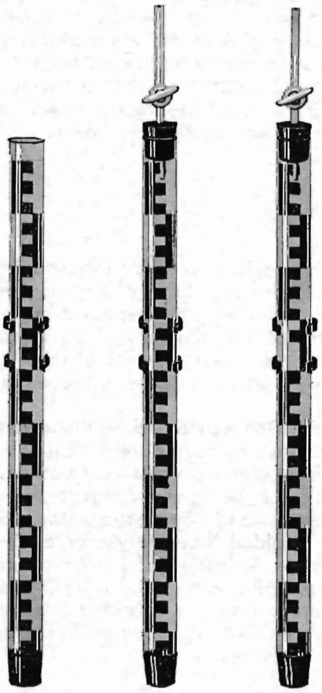
559 40
Nuclear emulsion plate; film with special emulsion, mounted on glass plates of approx. 76×26 mm² area.

The plates are exposed to cosmic radiation by conveying them to the stratosphere in balloons, or irradiated with high-energy protons in large accelerators. They are developed and fixed and are supplied and stored in closed polythene bottles with properly adjusted atmospheric moisture content. Each plate is accompanied by a sampling sheet on which about 10 important and typical events are marked, together with their coordinates and/or marking points. With the help of the mechanical stage (442 15) mounted on one of the microscopes (442 10/13 or 14) the events are easily located. Individual inspection is preferable to diaprojection. The latter requires a careful elimination of the ultrared component of the light, e.g. with copper sulphate solution in 10 mm deep plate glass boxes.

Description, Cat. No.	content	activity	γ-ray dose rate in μrem/h at a distance from the source of		sheathing of the source	Notes about storage
			1 m	0.5 m		
Shielded laboratory source of neutrons 559 30	Radium 226	3 mc	<600 outside the distance shield		Enclosed source with lead shielding, embedded in paraffin as moderator, with distance shield and safety lock	Do not leave accessible to unauthorised persons; avoid keeping inflammable substances in the neighbourhood.
Radium source on plate 546 44	Radium 226 and daughter products	5–10 μc	4–8	16–32	Rolled into a noble-metal foil; stored in a glass vessel with 8 cm diameter	This source should not be accessible to unauthorised persons
Thorium source 546 36, accessory to 546 25	Thorium 232 and its daughter products	1 μc	0.5–1	2–4	in solder-sealed polythene bottle protected against inadvertent escape of thorium	This source should not be accessible to unauthorised persons
Radioactive source for the expansion cloud chamber	Radium 226 and its daugther products	<0.1 μc	≤ 0.1	≤ 0.4	Rolled into a noble-metal foil; on a needle	This source should not be accessible to unauthorised persons
Spinthariscope 559 51	Radium 226 and its daughter products	0.01 μc	0.01	≤ 0.04	Contained in the phosphor	Avoid unsupervised use by juveniles
Source for the point counter 546 28	Radium 226 and its daughter products	0.001 μc	0.001	≤ 0.004	Mounted on a needle in such a manner that the source itself cannot be touched.	Avoid unsupervised use by juveniles

7.i, Experiments on radioactive decay

The laws of radioactive decay proceed according to an exponential law. Similar exponential decay laws are found in several other fields of physics. For this reason, several model experiments proceeding analogously to the processes in radioactive decay chains have been suggested. A particularly clear experiment can be derived from the use of the Hagen-Poiseuille-law for the flow of water through capillary filters because the height of the water column is a particularly clear visual measure of the hydrostatic pressure. Therefore we have developed capillary filter tubes with which exponential decay laws can be derived experimentally in a simple, illustrative and, if so desired, quantitative manner. (Cf. K. Hecht and A. Lindberg, experiments on exponential decay, MNU, 12, 344 (1960). The analogies between the experiments that can be performed with such capillary filter tubes and radioactive decay processes go so far that, for example, even the xenon poisoning of reactors can be represented by means of such capillary filter tubes. (Cf. "Nukleonik", vol. 2, No. 1, 1960, p. 37–38).



361 74

361 74

Capillary filter tubes, for an experimental derivation of the exponential function and for model experiments on all processes determined by this function, e.g. radioactive decay, radioactive equilibrium, charge and discharge of a capacitor, series disintergration, etc.

The equipment comprises 3 glass tubes, approx. 50 cm long, which are closed at one end by capillary filters. Water flows out from these tubes in such a manner that the height of the water column in the tube decreases exponentially with time. By choosing 3 different filters, different discharge rates with half-life periods between approx. 10 and 120 seconds are obtained.

Consisting of 3 tubes, 3 holders with scales for mounting the tubes on stand rods, 2 rubber stoppers with cocks for starting the discharge of water. Without stands. The parts can be ordered separately under the following catalogue numbers:

361 70	**Capillary filter tube, short half-life period** spare tube for 361 74
361 71	**Capillary filter tube, medium half-life period** spare tube for 361 74
361 72	**Capillary filter tube, long half-life period** spare tube for 361 74
361 73	**Holder** with scale, fitting the capillary filter tubes 361 70/71/72.

Cf. "LEYBOLD Physics Leaflets" DC 532.522.072; a : 539.16.01, DC 532.522.072 b; DC 532.522.072; c : 539.16.072, DC 532.522.072; d : 539.16.072, DC 532.522.072;e, DC 532.522.072; f :539.162.072, DC 532.522.072; g : 539.162.072

8. Experiments on artificial radioactivity

The laws radioactive decay proceed according to an expoproduced in a source of neutrons constructed for school purposes, is of particular advantage in teaching: the radionuclides are produced in very small quantities and have very short half-life periods of a maximum of a few hours. Therefore it is possible to observe the growth of activity up to saturation, and its decay, by measuring the half-life periods. And yet there will be no hazards to persons or contamination of rooms even in the case of grossly negligent handling of these substances. In this manner all those difficulties that occur when working with naturally radioactive substances or materials from reactors are avoided.

A source of neutrons that is to be used in teaching must satisfy particularly strict safety requirements. The source of neutrons described below satisfies these requirements: its activity is not large, but suffices in order to obtain clear results with the available measuring methods. The shielding is so carefully designed that even persons remaining in the vicinity of the source are not exposed to any hazards.

We suggest the following experiments that may be performed with the help of this source: Activation of silver and indium up to saturation, and observation of the decay of the activity. Activation of these substances. Determination of the half-life period of separated radioactive isotopes, chemical reactions with activated substances. – Absorption of thermal neutrons by cadmium and boron, estimation of neutron capture cross-sections, reflection of neutrons by paraffin wax.

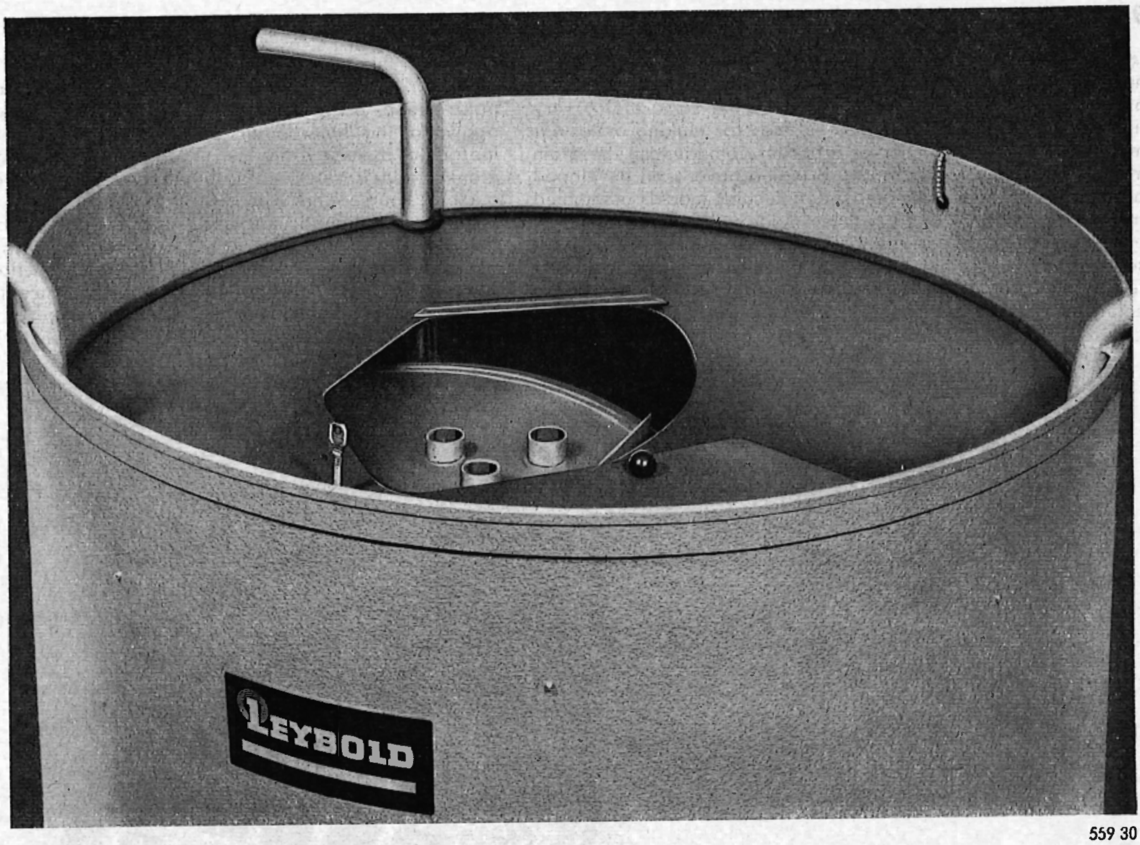
Safety considerations (re.: Source of neutrons, 3 mc, 559 30).

Our own detailed measurements on the source of neutrons were confirmed by a radiological test performed by the German National Physical Laboratory (Physicalisch-Technische Bundesanstalt). The official test report dated 9th July 1959 shows that the standard ion dose rate due to γ-radiation from the source does not exceed 0.7 mr/h at any point on the external wall and amounts to approx. 0.6 mr/h in the places scheduled for the sojourn of persons.

In the Federal Republic of Germany, the immediate surroundings of the source of neutrons are not considered "hot" and special measures of radiological protection are not, therefore, prescribed. But the possession and use of the source of neutrons is subject to a licence which is to be applied for through the competent Länder authorities. We are very willing to assist our customers in any problems that may arise in this context. – According to the same test report, the saturation activity that can be produced with this source is less than 0.05 μc and is, therefore, not subject to any control.

The source should be stored in such a manner that unauthorised persons have no access to it and that nobody remains continuously in the immediate vicinity of the source. Special measures of radiological protection are not necessary for the storage of the source.

The relevant regulations concerning this subject differ greatly in different countries, and therefore we must ask our foreign customers to make sure themselves that any laws that may be in force on the subject in their countries are adhered to.

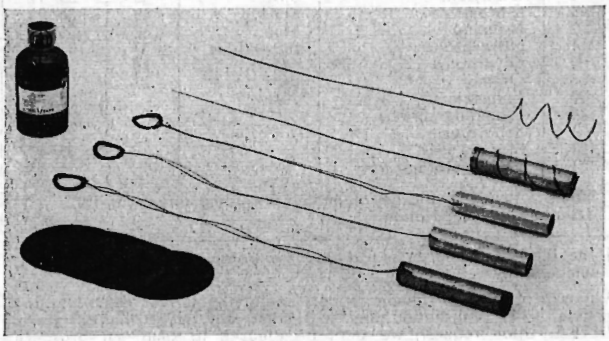


559 30

559 30

Shielded laboratory source of neutrons, 3 mc, for experiments on artificial radioactivity and on radio-chemistry. The apparatus contains a radium-beryllium source which is enclosed in a lead block and emits fast neutrons. The lead block is cast into a paraffin wax block serving as moderator and slowing down the fast neutrons to thermal velocities. Holes in the paraffin wax block at various distances from the source are provided for the insertion of the substances that are to be activated by irradiation.

On the outside, the radium-beryllium source is shielded by a sheet-metal distance shield which keeps the experimenter at a safe distance from the source. The source is eccentrically arranged within the lead block. The lead block is arranged at the centre of the paraffin wax block and the paraffin wax block is, in turn, eccentrically arranged within the distance shield. This arrangement facilitates experimenting with the source, because the radium-beryllium source is conveniently accessible from one side without the dose-rate being higher at this point of the distance shield.



559 35

Technical data:

Activity of the Ra-Be source: 3 mc

Total neutron flux: approx. 30,000 neutrons/second
Neutron flux density of thermal neutrons in the irradiation holes: approx. 100, 50, 25 neutrons per second (depending upon their distance from the source).

Activity of the irradiated samples: approx. 10^{-10} c

Maximum dose-rate outside the distance shield due to both γ-rays and neutrons: 0.6 mr/h

Size of the irradiation holes: approx. 30 cm long, dia. 3 cm

Paraffin wax block: dia. approx. 40 cm

Outer distance shield: dia. approx. 80 cm, 91 cm high
With strong lid and safety lock, on wheels, with handles.

The following ancillary equipment for experimenting is supplied with the source (and can, partly, also be ordered separately under Cat. No. 559 35):

Hollow cylinders made of silver (2×) and indium, cadmium capsule with holder, holder for other samples (2×), bottle with ethyl iodide, set of carbon filters, holder for test tubes by which they may be lowered into irradiation holes (5×), plastic bag for borax; without counting equipment (see p. 185).

559 35

Set of ancillary items for the shielded laboratory source of neutrons, consisting of: Hollow cylinders made of silver (2×) and indium, cadmium capsule with holder, bottle with ethyl iodide, set of carbon filters (5 filters). One set of ancillary equipment is supplied with the shielded laboratory source of neutrons (559 30).

9. Molecular models

In many organic compounds with homopolar bonds the internuclear distances and valency angles of the constituent atoms are so similar when the bond types are the same that a very limited number of atom models suffices for making molecular models of a great number of different compounds. The atom models according to Stuart and Briegleb have been developed on the basis of this principle. The molecular models assembled from these parts differ from those made with simple spherical or crystal lattice models in that they are true-to-nature, true-to-scale models in which the spatial extensions are correctly represented and internuclear distances and effective radii are enlarged 1.5×10^8-fold.

However, the possibility of making models with these properties for use in several compounds is restricted to the homopolar bond prevailing in organic chemistry and does not apply to the heteropolar or ionic bond predominating in inorganic chemistry. In the following we describe a set of atomic models selected to suit the requirements of an introductory course and with which the basic types of organic compounds (aliphatic, aromatic and cyclic hydrocarbons and the alcohols, acids, esters, etc., derived from them) can be demonstrated by means of simple examples. Phenomena which require for their understanding a spatial conception such as isomerism, optical activity and tautomerism, can be treated particularly well. (See coloured illustrations on p. 196).

357 88

357 88

Set of atom models for schools, for representing more than 150 aliphatic, aromatic and cyclic compounds. The models are coloured spheres or ellipsoids with cut surfaces which can be put together with press studs and separated with the help of a separator tool. Flat clamping springs mark double bonds which, in contrast to single bonds, do not allow the participating atoms to rotate independently. The set is supplied with a systematic chart of the models that can be assembled with it.

357 93

Storage tray for atom models (supplied with 357 88); plastic tray (32×54×10 cm³) with 40 pressed-in recesses for clear arrangement and storage of the set of atom models for schools (357 88). The recesses can be written on with soft pencil as often as desired, so that after using the models, they can be checked for completeness and put away without difficulty. If the collection is extended, further trays can rest upon the first.

357 94

Lid for the storage tray (357 93); supplied with 357 88.

The set consists of the following parts:

Number	Description	Colour	Max. dia. (mm)	Cat.-No. 1)
14	H	white	31	357 00
3	Cl	green	46	357 06
6	C-aliph	black	31	357 10
4	C-ethylene	black	48	357 11
6	C-arom	black	48	357 12
2	N-amino	blue	39	357 30
1	Nitro group	red + blue	67	357 33
2	O-carbonyl	red	46	357 50
6	O-ether	red	37	357 51
20	Connectors			357 90
14	Clamping springs			357 91
1	Separator			357 92
1	Storage tray			357 93
1	Lid for storage tray			357 94

Notes with systematic list of models including directions for assembly and separation.

1) The models can also be ordered separately under these catalogue numbers.

A new prospectus of atomic models containing further compilations of models is in preparation and will come out under the designation **PH 70 E.** Upon request, we shall be pleased to send our prospectus "Atom models for schools" to interested parties.

10. Crystal lattice models

After Laue had discovered crystal lattice interference, the structure of many crystals was studied by means of X-rays and electron beams. The knowledge derived from these data has been utilised for the construction of clear crystal lattice models which promote a spatial conception of the various lattice types.

From the large number of models supplied by us we have selected the ones that are particularly useful in teaching, and put them together in three sets:

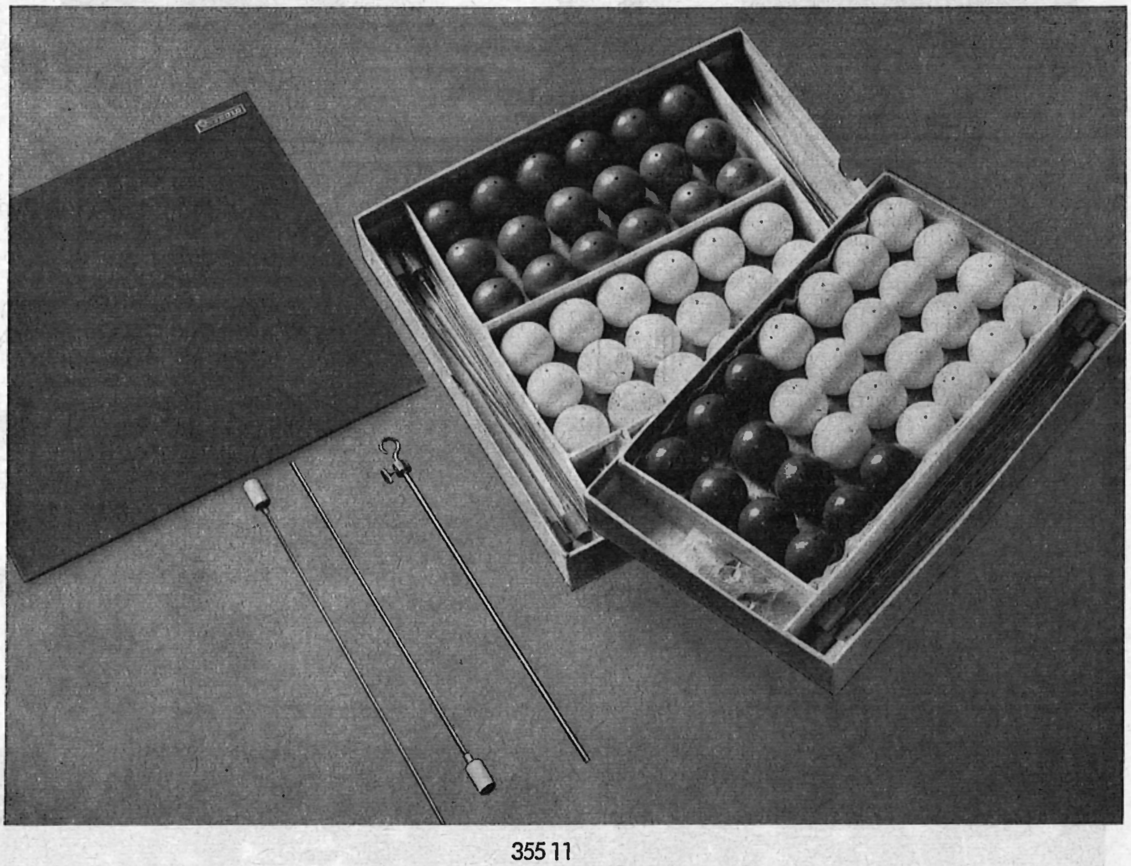
1. One set of 14 space lattices according to BRAVAIS containing the basic types from which most of the naturally occurring crystal lattice types are derived.
2. A basic set of the most important structural types with which the space lattice of the substance, the arrangement of its components, the origin of important crystallographic surfaces and the characteristic symmetry properties can be made clear and related to the optical and mechanical properties of the crystal.
3. A further teaching aid which is of particular value to the learner consists of lattices which are assembled from spheres and needles. This method forces the learner to think clearly about each type he wants to represent and is a good training in spatial visualisation.

353 20

Basic set of crystal lattice models, containing the nine most important structural types, viz. the crystal lattice models of copper, magnesium, diamond, rock salt, graphite, caesium chloride, wurtzite, calcite (calc spar), and a general triclinic space lattice.
The crystal lattice models are assembled from spheres having a diameter of 20 mm which are permanently connected to one another by means of metal rods. Where this seemed necessary, different colours were chosen for the spheres. The linear magnification is 250 million fold, so that 1 nm is represented by a length of 25 cm.
These lattice models can also be ordered separately.

353 00

Set of 14 BRAVAIS type space lattice, containing the seven primitive space lattices originally described by A. BRAVAIS in 1848, which correspond to the seven crystal systems, and moreover seven other space lattices which link up with the first seven by being body-centred or face-centred.
These 14 lattice models represent the basic types from which practically all naturally occurring crystal types are derived. The lattice models with an edge length of approx. 15 cm are assembled from 9 to 14 spheres of 25 mm diameter which are permanently connected to one another by means of metal rods.
(See illustrations on p. 196)



355 10/11

355 10

Set of parts for assembling crystal lattice models according to Dr. Peter[1]), for assembling crystal lattice models from spheres that are arranged on steel needles at various heights.
The steel needles are held on a base plate at any desired spacing by means of magnets.

The set contains: one base plate, 30×30 cm² in size, 18 steel needles with magnetic feet, 18 red and 18 white spheres, 50 rubber platelets and one adjusting rod.

355 11

Supplementary set of parts for assembling crystal lattice models offering considerably greater possibilities, also for assembling more complicated models; consisting of: 14 steel needles with magnetic feet, 18 white and 10 green spheres, and 50 rubber platelets.

Upon request we shall be pleased to send you our list **PH 48-2** containing a systematic representation and a list of all important crystal lattice types.

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[1]) Described in the journal MNU, vol. XI, No. 8, pp. 353–361.

Optical isomerism

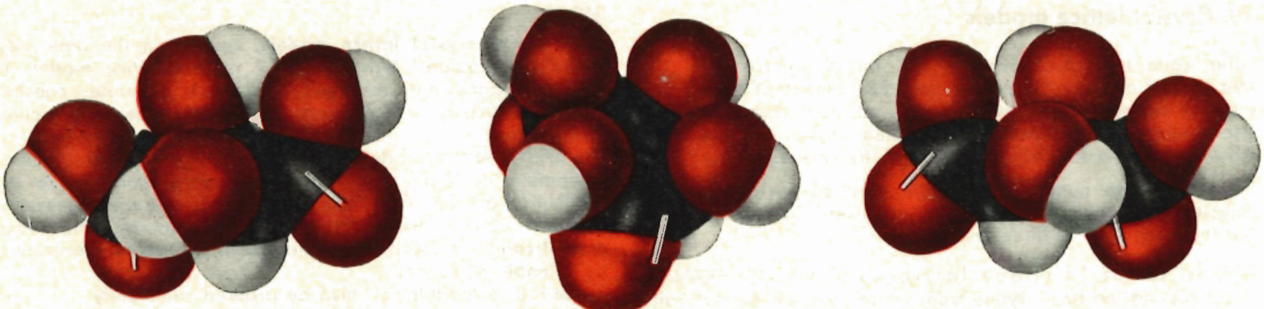


Fig. 124 **Optical isomerism represented by means of the classical example of the three isomeric tartaric acids.** PH 1001
On the right and left, the d- and l-tartaric acids, which are enantiomorphic to, i.e. mirror images of, one another. In the centre, mesotartaric acid in which two halves of the molecule are enantiomorphic to one another, i.e. the molecule consists of two symmetrically opposed halves, and the optical activity of the active C-atoms is, therefore, mutually compensated for. The CHOH-COOH-groups of the two active forms prove identical upon rotation through 180° and will therefore rotate polarised light in the same sense. For greater clarity no attention was paid in Fig. 124 to the most favourable spatial arrangement of the atoms as far as energy is concerned.

Tautomerism, at the same time demonstration of a hydrogen bridge

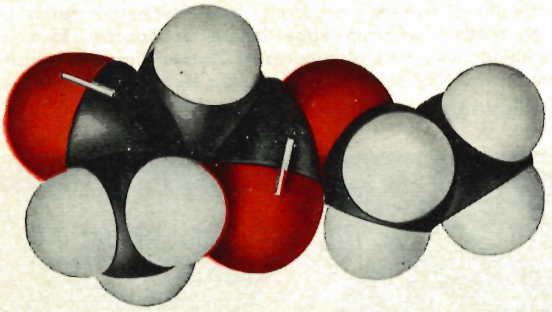


Fig. 125 **Acetic acid ester, keto form** PH 1002
Most favourable arrangement of the carbonyl group as far as energy is concerned. The C=O bond being a π-bond has its greatest radius of action at right angles to the plane of the molecule.

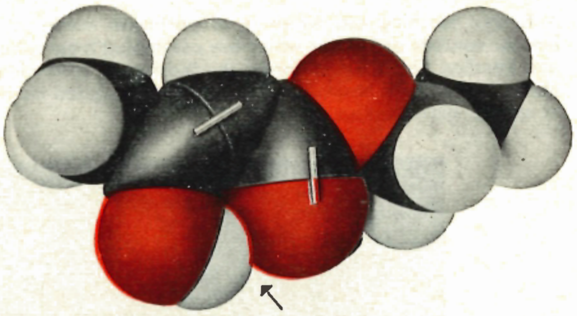
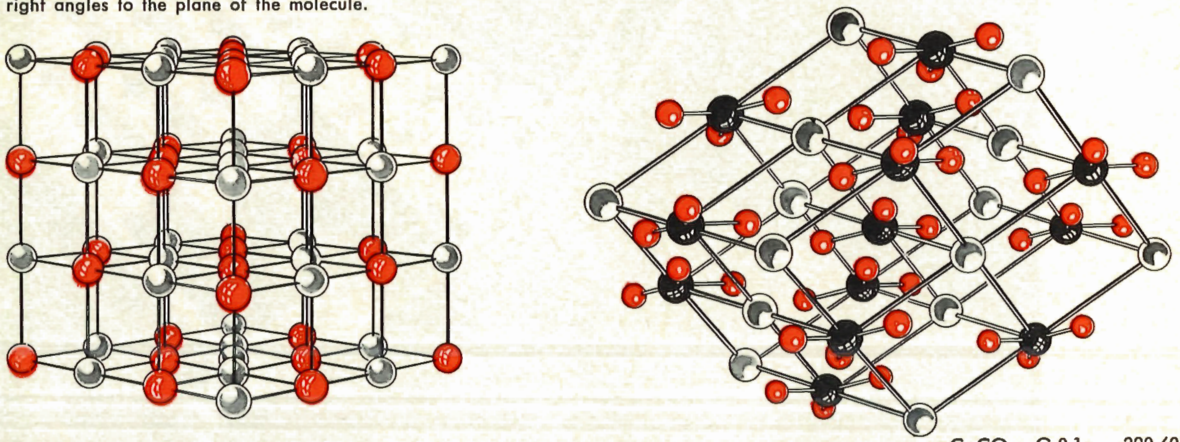


Fig. 126 **Acetic acid ester, enol form** PH 1003
The hydrogen of the enol group forms a hydrogen bridge (see arrow) towards the carbonyl oxygen.



NaCl B 1 : 320 101

CaCO₃ G 0.1a : 320 601

Rock salt and calc spar crystal lattice models from the basic set of the nine most important structural types.

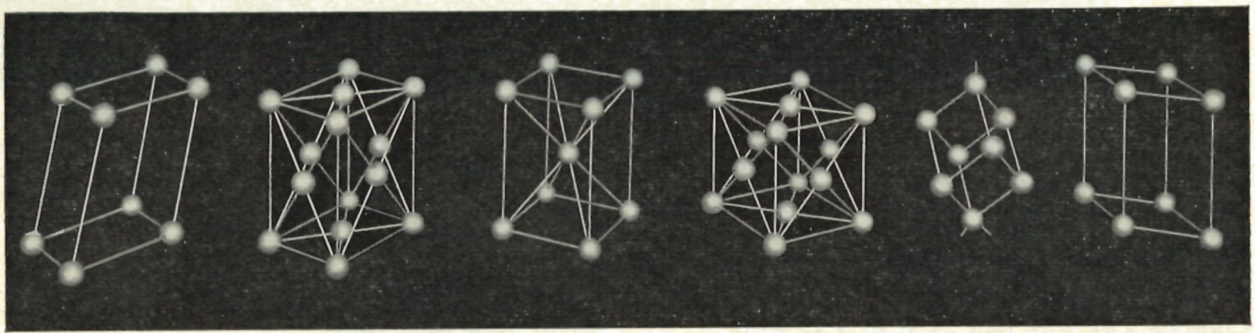
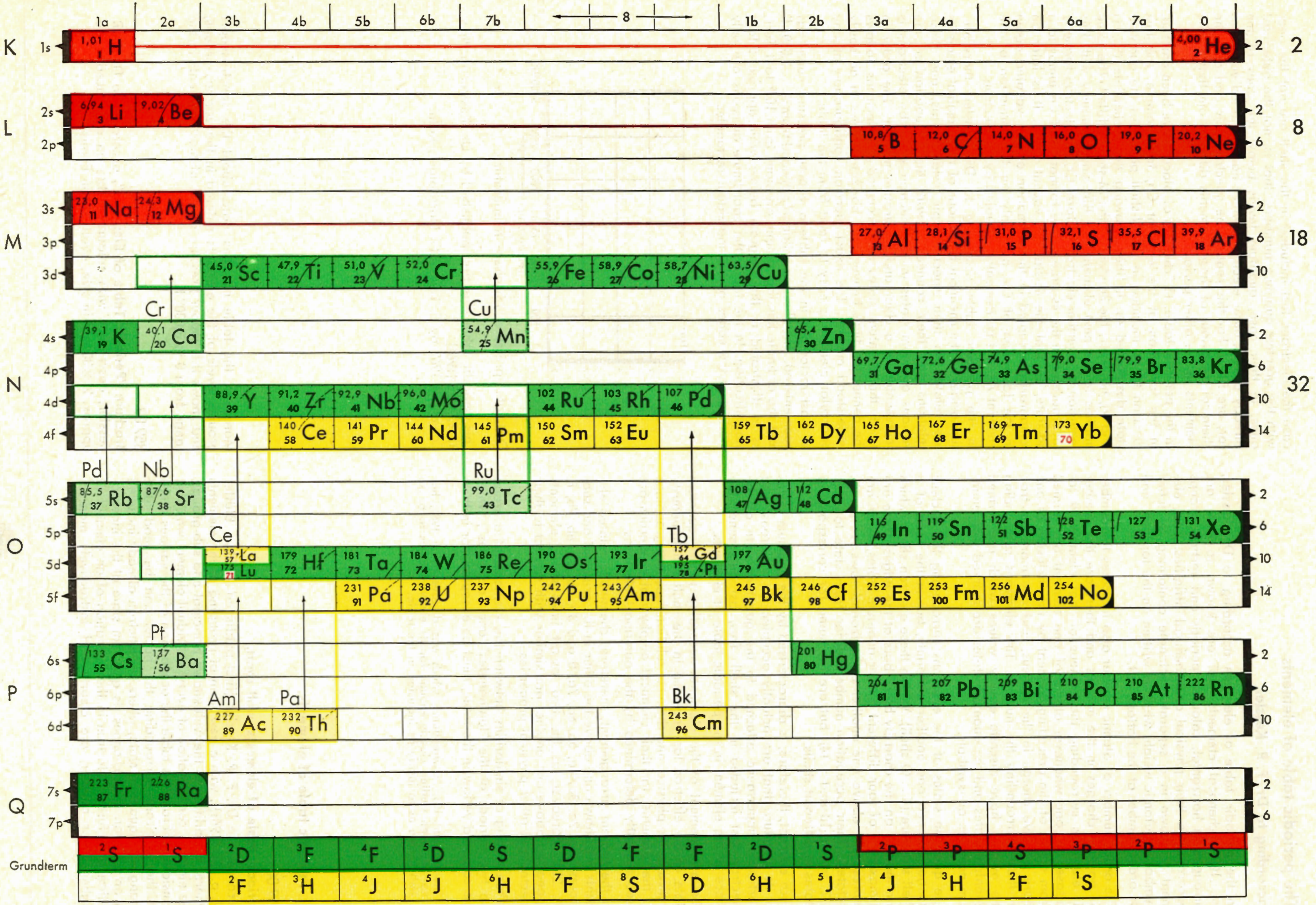


Fig. 127 **Unit cells from the set of 14 space lattice models** PH 1251
(from left to right): triclinic lattice, rhombic face-centred lattice, tetragonal body-centred lattice, cubic face-centred lattice, rhombohedric lattice, hexagonal lattice.

11. Periodic system of elements (description overleaf)


1a
2a
3b
4b
5b
6b
7b
8
1b
2b
3a
4a
5a
6a
7a
0
K
1s
1,01 1 H
4,00 2 He
2
2
L
2s
6,94 3 Li
9,02 4 Be
2
2p
10,8 5 B
12,0 6 C
14,0 7 N
16,0 8 O
19,0 9 F
20,2 10 Ne
6
8
M
3s
23,0 11 Na
24,3 12 Mg
2
3p
27,0 13 Al
28,1 14 Si
31,0 15 P
32,1 16 S
35,5 17 Cl
39,9 18 Ar
6
18
3d
45,0 21 Sc
47,9 22 Ti
51,0 23 V
52,0 24 Cr
55,9 26 Fe
58,9 27 Co
58,7 28 Ni
63,5 29 Cu
10
Cr
Cu
N
4s
39,1 19 K
40,1 20 Ca
54,9 25 Mn
65,4 30 Zn
2
4p
69,7 31 Ga
72,6 32 Ge
74,9 33 As
79,0 34 Se
79,9 35 Br
83,8 36 Kr
6
32
4d
88,9 39 Y
91,2 40 Zr
92,9 41 Nb
96,0 42 Mo
102 44 Ru
103 45 Rh
107 46 Pd
10
4f
140 58 Ce
141 59 Pr
144 60 Nd
145 61 Pm
150 62 Sm
152 63 Eu
159 65 Tb
162 66 Dy
165 67 Ho
167 68 Er
169 69 Tm
173 70 Yb
14
Pd
Nb
Ru
O
5s
85,5 37 Rb
87,6 38 Sr
99,0 43 Tc
108 47 Ag
112 48 Cd
2
5p
115 49 In
119 50 Sn
122 51 Sb
128 52 Te
127 53 J
131 54 Xe
6
Ce
Tb
5d
139 57 La
175 71 Lu
179 72 Hf
181 73 Ta
184 74 W
186 75 Re
190 76 Os
193 77 Ir
157 64 Gd
195 78 Pt
197 79 Au
10
5f
231 91 Pa
238 92 U
237 93 Np
242 94 Pu
243 95 Am
245 97 Bk
246 98 Cf
252 99 Es
253 100 Fm
256 101 Md
254 102 No
14
Pt
P
6s
133 55 Cs
137 56 Ba
201 80 Hg
2
6p
204 81 Tl
207 82 Pb
209 83 Bi
210 84 Po
210 85 At
222 86 Rn
6
Am
Pa
Bk
6d
227 89 Ac
232 90 Th
243 96 Cm
10
Q
7s
223 87 Fr
226 88 Ra
2
7p
6
Grundterm
²S ¹S ²D ³F ⁴F ⁵D ⁶S ⁵D ⁴F ³F ²D ¹S ²P ³P ⁴S ³P ²P ¹S
²F ³H ⁴J ⁵J ⁶H ⁷F ⁸S ⁹D ⁶H ⁵J ⁴J ³H ²F ¹S

Grundterm = ground level

The periodic table of elements

according to Dr. F. R. Kessler

In the periodic table of elements according to Dr. Kessler, the 102*) chemical elements that are known to date are arranged in horizontal, coloured periods and vertical groups according to their physical and chemical affinities. Each element is shown in a separate rectangle containing its letter symbol, its atomic weight which is written on the top, left, and its order number at the bottom, left.

The order number or atomic number also indicates the number of positive charges in the nucleus and therefore the number of electrons surrounding the nucleus of that element. It increases by one whenever atoms of one element are formed from atoms of the preceding element by the inclusion of one more positive charge in the nucleus, and one more electron in those surrounding the nucleus. The electrons surrounding the nucleus have discrete energy values which are termed quantum states and the quantum states are marked with quantum numbers or -symbols.

The quantum states of the electrons surrounding the nucleus do not succeed one another uniformly, but in the form of a shell structure (K . . Q shell). Within these electron shells, which are marked on the chart by black bars at the edges, there are a maximum of four different further quantum states, which are represented above one another in horizontal rows (s-, p-, d-, f-states). Their occupation numbers differ from state to state s: 2, p: 6, d: 10 and f: 14), but are the same for corresponding states in different shells.

Each element, therefore, is characterised by the quantum states in its structure that are actually occupied by electrons, and particular importance attached to the quantum state of the electron last included in the shell. This last determines the place of the element in the periodic table of elements.

The arrangement of the elements according to the quantum state of the electron last included in the shell simultaneously indicates the physical and chemical relationships and groupings of the elements, for their chemical or physical properties are predominantly determined by the outermost electrons.

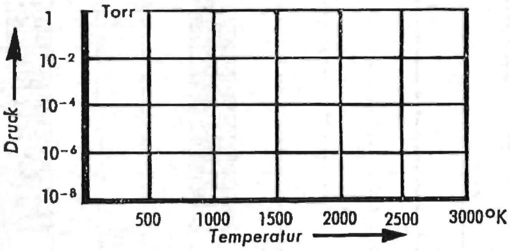
In the present arrangement, therefore, chemically related elements are shown one above the other in the principal and subgroups (1a, 2a, 3a, 4a, 5a, 6a, 7a, 0 and 3b, 4b, 5b, 6b, 7b, 8, 1b, 2b). Moreover, as the two lowest lines show, elements appearing above one another are similar with respect to their spectra and other physical properties.

When talking of similarities between the elements of a group the two periods of the "lanthanides" and "actinides", which are coloured yellow in the table, must be excepted, for in their case the electrons last included in the shell are not the ones with the greatest quantum numbers, that is, not the outermost ones. In their case, quantum levels below the ones of the already built-in outer electrons, which had remained vacant so far, are filled. For this reason the spectroscopic and also the chemical behaviour of these elements differs from that of the elements in the other periods.

In the periodic table, 11 "changes of place" have been entered. In the formation of the element Ca, for example, the last electron to be included in the N-shell possesses the quantum state designated 4s. In the following three elements (Sc, Ti and V), however, the 3d-state of the M-shell is filled. The same applies to the next element, Cr. But simultaneously with this inclusion of a further electron to form Cr, the electron formerly incorporated in the 4s-state in the formation of Ca jumps to a 3d-state, so that the 4s-state is vacant again. It is later on temporarily occupied in the formation of Mn, vacated again in the formation of Cu, and only on the formation of the element Zn is it permanently occupied by an electron.

In the periodic table according to Dr. Kessler, therefore, similarities in the chemical behaviour of the chemical elements are related to their spectroscopic relationships, and these relations and their connection with the occupation of the various quantum states in the electron shells by electrons is represented in a clear and illustrative manner. The order in which the quantum states are occupied by electrons follows the connecting lines between the horizontal rows in an easily understood manner. The exact electron configuration of any particular element is easy to read from the table.

In most rectangles in the table a vapour pressure curve has been entered. The abscissa is linearly divided from 0 . . . 3,000° K and the ordinate has logarithmic divisions from 10^{-8} to 1 Torr, as is illustrated in the diagram below with approx. 5-fold magnification. In the table, the coordinate divisions are only marked at the edges of the individual rectangles.



Ordinate: pressure; abscissa: temperature.

This periodic table was first published by Dr. Kessler in Phys. Bl. **17**, 270 (1961).

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*) The element 103, "Lawrentium", which was discovered in 1961, has not yet been studied closely enough for its electron states to be so well known as to justify its inclusion in the table.

11. Periodic table of elements.

359 00

Periodic table of elements, wall chart,

according to Dr. F. R. Kessler [first published in Phys. Blätter **17**, p. 270 (1961)], with a new form of grouping of the elements where, in addition to the well-known principal and sub-groups, the electron configuration of every individual element was also considered. From this table the occupation of the various shells of the electrons surrounding the nuclei can be read, and changes of quantum state, where an electron already included in an electron shell changes its quantum state at the incorporation of a further electron in the formation of an element of higher order number, are clearly and instructively marked.

Moreover, the table contains data about the spectroscopic ground levels of the elements entered in the various groups, and shows the vapour pressure curves of most elements in the range from 0 to 3,000° K.

359 02

Brochure **"Periodic Table of Elements"**, according to Dr. F. R. Kessler, description with coloured table on a reduced scale, approx. 21×30 cm² in size, available in English.

COLLECTIONS OF APPARATUS

We can offer a variety of collections of apparatus specially suited to the individual needs of different categories of schools and syllabuses. The range covers Primary Schools up to Universities.

The collections of apparatus include both apparatus for demonstrations and practical class work.

In addition to the collections or kits of apparatus mentioned in this catalogue, we offer the service of specialised staff to make out detailed lists of apparatus that you may require. All you have to do is to send in details of your requirements, syllabus to be covered, funds available, and our staff will do the rest.

The following collections of apparatus and kits are the ones most frequently sought after, and have, therefore, been given individual catalogue numbers. These will give you some idea of the kind of apparatus available. Two points, however, should be noted:

1) Collections of apparatus are made up of individual items to be found in this catalogue.

2) Kits are made up of apparatus specially designed for that purpose, of which all parts are interrelated.

All items in both the collections of apparatus and the kits can be ordered individually. The cost, however, is usually higher than when they are purchased in the form of a collection or a kit.

Collection of apparatus "GS"

598 20

Collection of apparatus Ia, fundamental set, comprises approx. 130 pieces of apparatus for performing physics experiments in: mechanics, vacuum, heat, optics, oscillations, magnetism and electricity. We recommend this collection for demonstrations in all types of secondary school.

In the descriptions of experiments supplied free of charge with this set, 130 experiments are described that can be performed with the apparatus from this collection. The set can be stored in a particularly convenient manner in the cabinet (598 35). Details and a list of the apparatus contained in this collection are given in our list GS which we shall be pleased to send you on request.

598 21

Collection of apparatus Ia in storage cabinet, same as for Cat. No. 598 20, but contained in a storage cabinet.

598 25

Collection of apparatus Ib, supplementary set for the above, contains about 60 pieces of apparatus and brings the fundamental set up to the complete collection of apparatus "GS" (598 30). All the experiments described in the descriptions of experiments VA 1 to VA 7 can be performed with these two sets. The apparatus of collection Ib can be kept in the cabinet (598 35) in addition to those of collection Ia. For details and a list of the apparatus contained in this set see our list GS which we shall be pleased to send you on request.

598 30

Collection of apparatus "GS", Set II, consisting of the fundamental set, Collection Ia, and the supplementary set, Collection Ib.

The set contains apparatus for experiments from the fields: mechanics, vacuum physics, heat, oscillations and waves, acoustics, magnetism, electricity and experiments with electric machines. Details and a list of the apparatus included in the set will be found in our list GS, which we shall be pleased to send you on request.

The set consists of approx. 200 pieces of apparatus for which approx. 200 experiments are described in the Manuals of Experiments (VA 1–VA 7) which form part of our set. (For the titles and Cat. Nos. of the individual Manuals of Experiments, see p. 207).

The entire collection can be stored very conveniently in our storage cabinet (598 35), which was specially developed for it.

598 31

Collection of apparatus "GS", Set II, in storage cabinet, same as for Cat. No. 598 30, but in storage cabinet (598 35).

598 35

Storage cabinet for the collection of apparatus "GS"; two-piece cabinet for convenient storage of the collection GS, or of the fundamental set Ia and the supplementary set Ib.

The cabinet is 1.20 m wide, 1.90 m high and 0.50 m deep. It contains 11 portable drawers, some of them subdivided into compartments, and 4 shelves. These storage facilities are provided with plates showing illustrations of the apparatus to be stored at the places where the plates are mounted. This makes it easy for a teacher or for a child helping him to tidy away the apparatus after use and to keep it properly arranged. The bottom part of the cabinet has a base.

If the top and bottom of the cabinet are not to be set up one on the other, but side by side, an additional base and a cover plate can be ordered under catalogue number (598 02).

When ordered together with one of the sets of apparatus Cat. No. 598 20 or 598 30, this cabinet is sold at a reduced price.

601 90
Collection of chemistry apparatus (GSC)
602 00
Cabinet for the collection of chemistry apparatus (GSC)
For descriptions and illustration, please see p. 209.

The Basic Physics Kit (BPK)

591 90

Basic Physics Kit (BPK) for primary and secondary schools, for practical work in general science and the earlier stages of physics. The set of apparatus consists of approx. 55 individual parts. Owing to each part having a variety of uses, this set is particularly economical and is designed with an entirely modern approach to the conceptual unity of the subject. The apparatus is suitable for work in groups of 2–4 pupils.

The set can be supplemented by:

591 05 **Power pack*),** required if there is no central current supply to the pupils' workbenches;
(Each working place must be provided with: A.C., loadable up to 10 A, 0–12 V, variable in steps of 4 V; D.C. loadable up to 3 A, 0–12 V, variable in steps of 4 V; D.C. 4 V, 9 A).
590 91 **Electrical meter,** with safety device
590 92 **Series resistor, 12 V,** for same
590 93 **Shunt resistor, 12 A,** for same
590 94 **Direct connection attachment, 2 mA/50 mV,** for same
590 96 **Shunt resistor, 1.2 A,** for same
[This instrument is required for quantitative electricity experiments. Further attachments for further extending its measuring ranges to include more advanced work are available (1.2 V, 0.12 V, 0.12 A)].

*) Technical data are contained in our special catalogue PH 65 E, which we shall be pleased to send you on request.

591 91

Cupboard (dimensions: length 98 cm, width 53 cm, depth 21 cm) for storing one set of apparatus BPK (591 90) and the power pack (591 05) as well as the electrical meter (590 91) with the attachments (590 92–96).

This cupboard is recommended in the event that a school is not likely to obtain more than one (or perhaps two) BPK sets, for example, small country schools with only a few children in the upper classes. If, however, the eventual acquisition of further BPK sets in envisaged, it is more advisable to order the cabinet 591 94 which will store 4 complete sets. The cupboard is easy to keep anywhere, for

- it can be carried and put down like a suitcase,
- it can be mounted on a wall like a cabinet,
- it can be put upright like a cupboard.

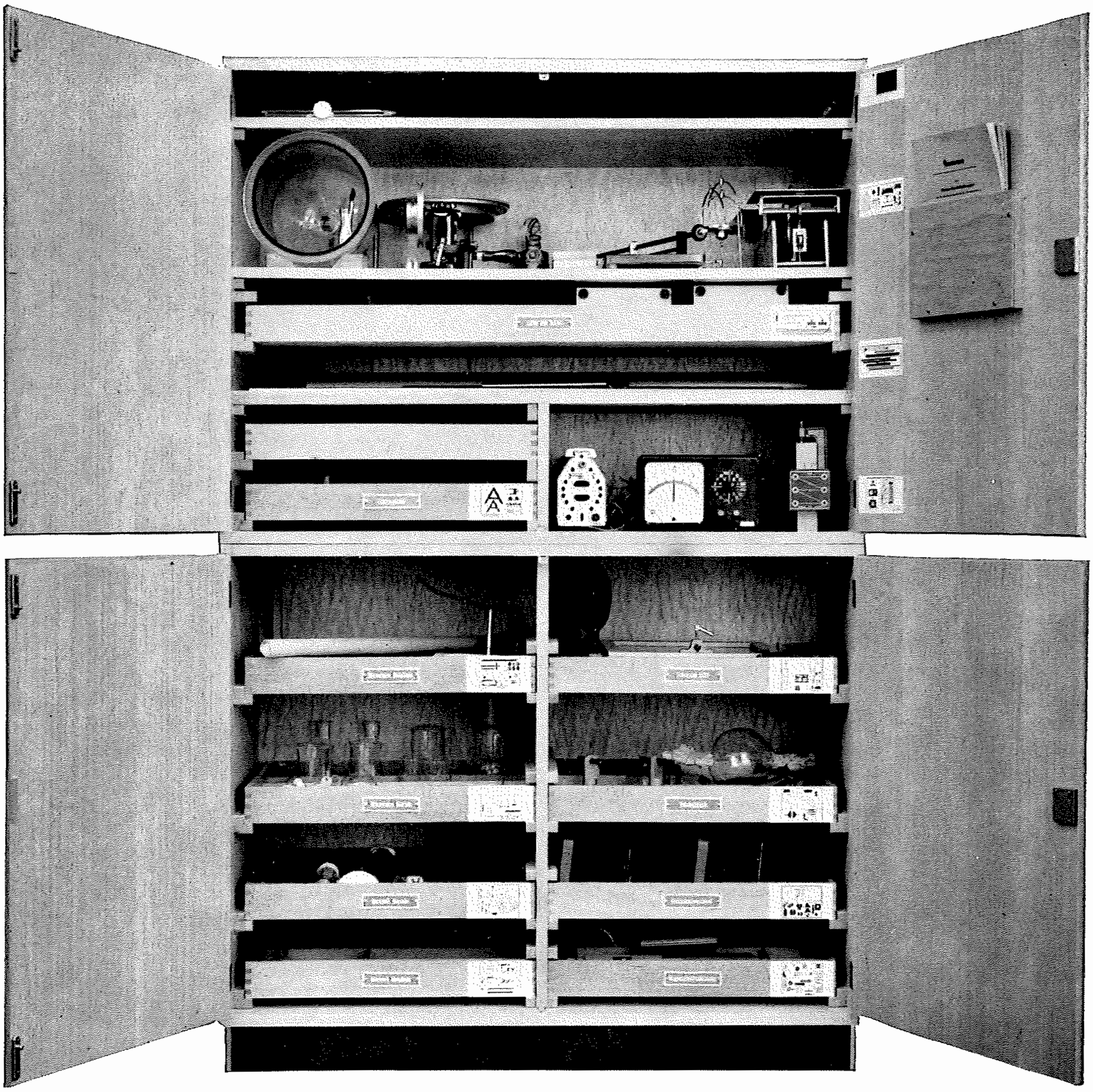
591 94

Cupboard "Organisat", (dimensions: width 120 cm, height 100 cm, depth 50 cm), for storing 4 complete sets of the Basic Physics Kit (BPK) (591 90) complete with power packs (591 05), electrical meters (590 91) and attachments (590 92–96) and the experiment cards (592 03).

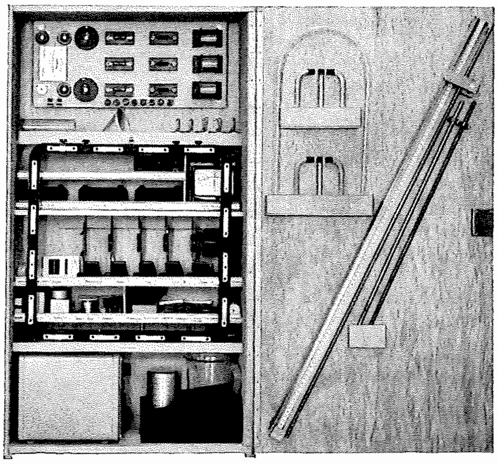
For every 4 identical pieces of apparatus, the cupboard contains a drawer with name and illustration of the part in front. Thus it becomes a matter of a few moments to hand each group the parts required for the experiment allotted to them. The 4 drawers with the most frequently used parts – the multi-purpose mounting frames – occupy the whole width of the cupboard.

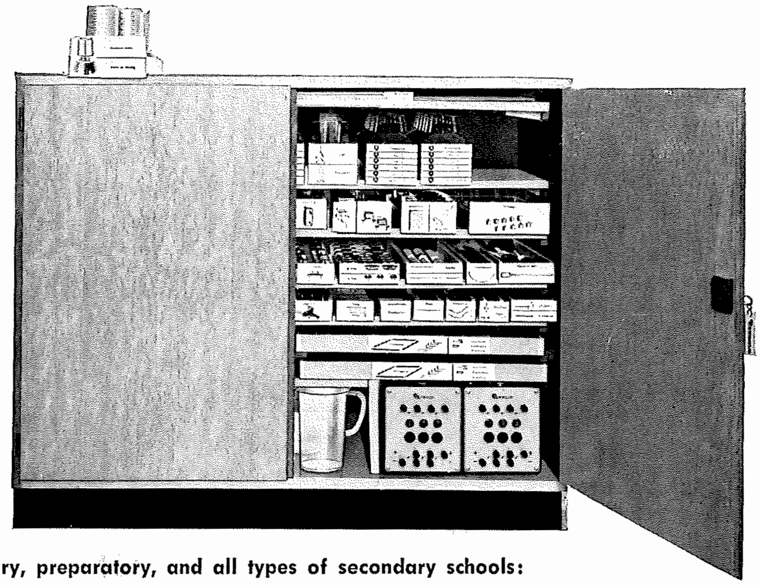
The particular advantages of this method of storage are the tidy and clear arrangement in a small space and the speed with which the apparatus

can be put together, distributed, tidied away and (after the practical lesson) checked for completeness.



Collection of apparatus "GS", Set II, in storage cabinet (598 31)



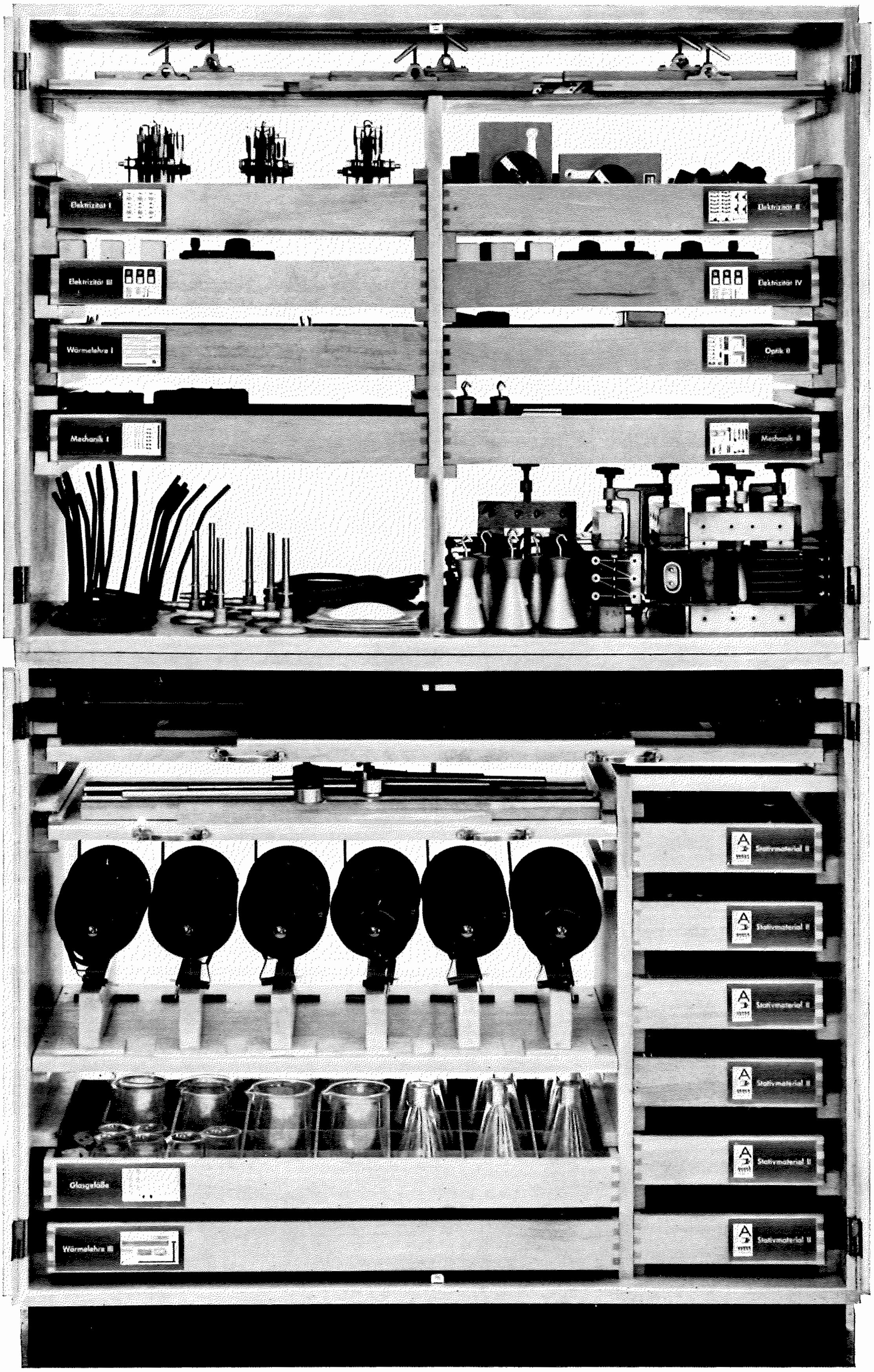


Basic Physics Kit (BPK) for primary, preparatory, and all types of secondary schools:

One set of practical work equipment (591 90)
with supplementary parts in cupboard (591 91).

Four sets of practical work equipment (4×591 90)
with supplementary parts in cupboard "Organisat" (591 94).

LEYBOLD



Two-piece cabinet with 6 sets of apparatus for practical work (598 01).

PLATE XII

592 00

File cover for literature (592 01). This file cover is recommended if a simple file seems unsuitable and if the student's notes are to be kept permanently.

592 01

Student's notes, in tear-off block. The block contains approx. 80 perforated sheets with descriptions of experiments that can be performed with the Basic Physics Kit (BPK), protected by the cover leaf of the block. The descriptions contain a short introduction to the problem, starting from a process known in daily life. This is followed by directions on how to perform the experiment, and questions concerning the evaluation of the experiment. The manuals of experiments are intended for use throughout a 4–5 years' syllabus and one block should be obtained for each pupil.

592 02

Teacher's notes, in file cover. The same contents as in the student's notes. However, these teacher's notes include the solutions of the problems and are printed on cardboard. The approx. 80 teacher's notes are filed in a file cover.

592 03

Experiment cards, approx. 80 index cards containing, unlike the texts on the teacher's and student's notes, only data on how to perform the experiment. These should be kept in the same place as the BPK sets and only handed singly to the groups of students actually performing the experiment. They are covered with plastic, and are therefore very durable as well as washable. In box (592 04), for which there is room in the cabinet, the cards for 4 working groups can be kept. The index cards are not necessary if each pupil has the tear-off sheets (592 01).

592 04

Box for experiment cards, with dividers and guide cards for 12 sets of experiment cards for a quick locating of the cards that are to be given out.

More advanced practical work in secondary schools of all kinds

598 01

Storage cabinet with 6 sets of apparatus, consisting of the two-piece cabinet (598 05) and the six sets of apparatus for practical work (598 04).

598 02

Base and cover plate, for the lower part of the two-piece cabinet (598 05 and 598 35). This base is required when the two parts of the cabinet are to be set up side by side.

598 04

6 Sets of apparatus for practical work, in the middle and, to some extent, upper stages of secondary schools, enabling 6 groups of pupils to do the same experiment simultaneously. Each set of apparatus comprises more than 100 parts for the experimental treatment of mechanics, heat, optics, and electricity. Each set of apparatus is supplied complete with manuals of experiments.

The sets are assembled from parts listed in this catalogue after consultations with specialised teachers. In the special prospectus mentioned below, the catalogue numbers of these individual pieces of apparatus are given.

Generally, 6 sets of apparatus enabling 18 pupils to do the same experiment simultaneously, working in groups of three each, are ordered. However, the sets can also be ordered singly.

If apparatus can only be procured gradually over a period of time, it is also possible to start by ordering a six-fold set of apparatus to cover one single field (for example, mechanics, heat, etc.) so that all the pupils can start their practical work simultaneously in this one field. Later, further apparatus can be ordered to obtain a complete set.

For convenient storage of the six sets of apparatus, and for easier organisation of the distribution of apparatus in practical work, we have devised the cabinet (598 05).

The sets of apparatus have been selected for the requirements of the practical work in the middle and upper forms of all kinds of secondary school, and cover all but the most advanced topics in modern physics, etc. For more information see our special prospectus, which we shall be pleased to send you on request.

For advanced practical work in the upper classes and the apparatus required, we shall be pleased to work out special quotations.

598 05

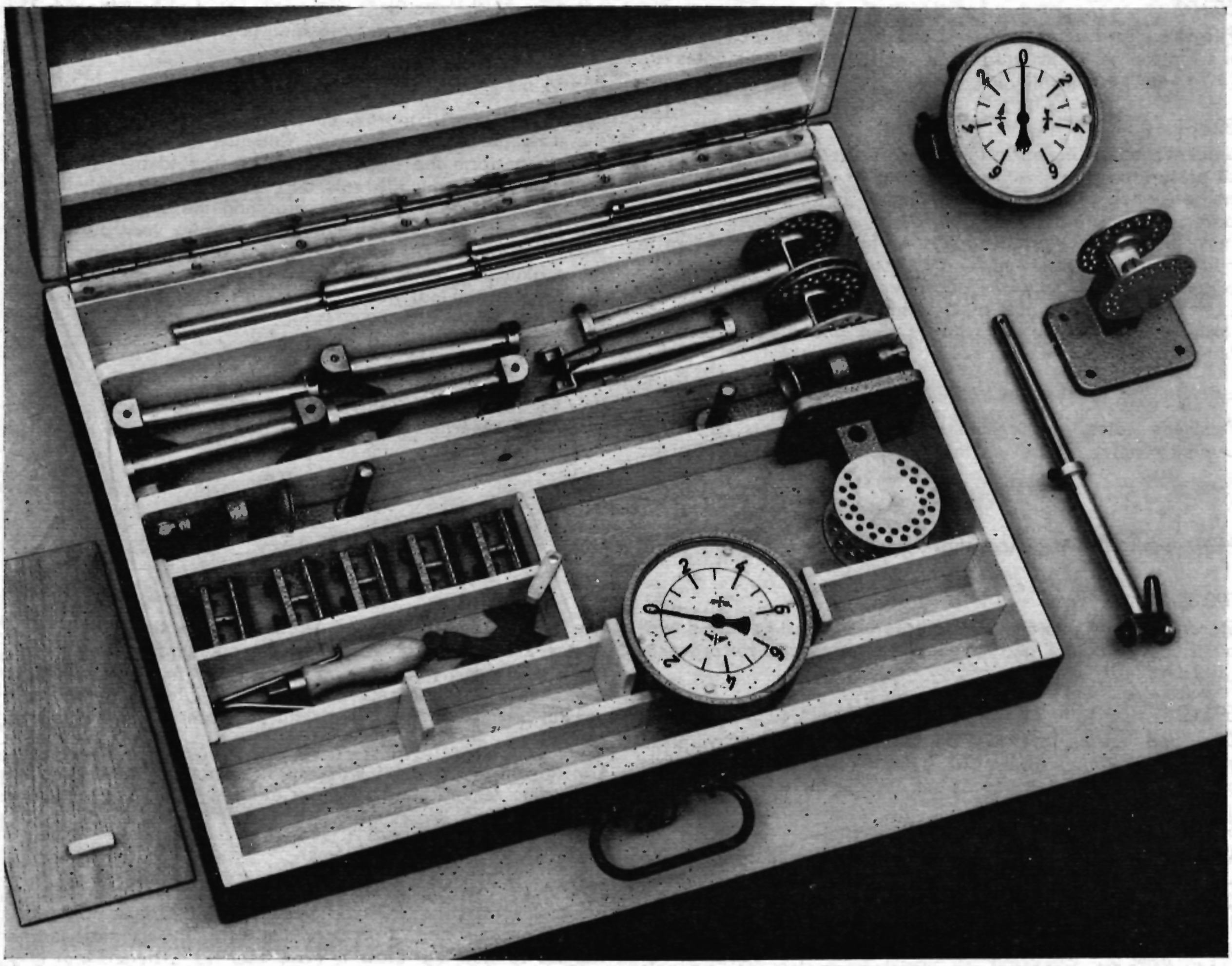
Two-piece cabinet, for convenient storage of the 6 sets of apparatus for practical work in schools, and for more convenient organisation of the practical work. The dimensions and weights of the filled drawers have been so arranged that they can be carried by pupils. The boards and shelves are marked with plates stating the names of the apparatus to be kept there, and a symbolic drawing of them. This makes it easier for the pupils to tidy away their apparatus and keep proper order, and the teacher has less trouble in checking for completeness at a glance.

The cabinet is 1.20 m wide, 1.90 m high and 0.50 m deep. It contains 22 drawers, partly subdivided into compartments, 2 shelves that can be partly drawn out up to a stop, 4 fixed shelves, 6 storage racks for optical parts, and 6 small cable boards.

The lower part is provided with a base.

If the upper and lower part of the cabinet are to be arranged side by side, instead of on top of one another, then one additional base and one cover plate (598 02) must be ordered in addition.

If ordered with 6 sets of apparatus for practical work in schools as per Cat. No. 598 04, the two-piece cabinet is supplied at a reduced price.



343 61

Strut-and-tie apparatus (Statics demonstration set)

The representation of force vectors of various directions and magnitudes has so far been restricted to experiments with spring balances such as are contained in the apparatus for demonstrating the parallelogram of forces according to Prof. Maey. But with arrangements of this kind, that is, with spring balances alone, the interaction of tension and compression forces in mechanical assemblies cannot be studied.

The strut-and-tie apparatus with its individual parts permits a large number of structures, such as triangles, parallelograms, roof trusses, bridge structures, etc., to be assembled, the experimenter being able to provide gauges at any desired measuring point of the arrangement.

Measuring points are those places in the arrangement where two rods are joined by a boss.

If the direction and magnitude of the force occurring in a rod is to be determined, the boss is replaced by a tension and compression gauge. The tension and compression gauge then, besides its function as a gauge, also takes over the mechanical function of the boss. Once, therefore, a structure has been assembled, the gauge can successively be inserted at each joint. In the case of larger assemblies several gauges may be used to measure a corresponding number of tension and compression forces simultaneously.

In this manner the set permits the performance of a large number of experiments which could not hitherto be treated experimentally.

We supply the strut-and-tie apparatus in two designs: a basic set (343 60) which will be of interest in teaching mechanics and applied mathematics in secondary schools in a realistic and practical manner, and an experimenting set (343 61) for technical colleges, schools of building and architecture, etc.

343 60

Strut-and-tie apparatus, basic demonstration set, consisting of the parts shown in the table. The set permits the assembly of a simple triangle and can be used as an introduction to the basic laws of statics.

343 61

Strut-and-tie apparatus, experimenting set, consisting of the parts shown in the table. The experimenting set, with which triangles, parallelograms, roof trusses and bridges can be assembled, makes possible the performance of a variety of statics experiments, such as the principle of a simple arched bridge shown by Fig. 128 (overleaf).

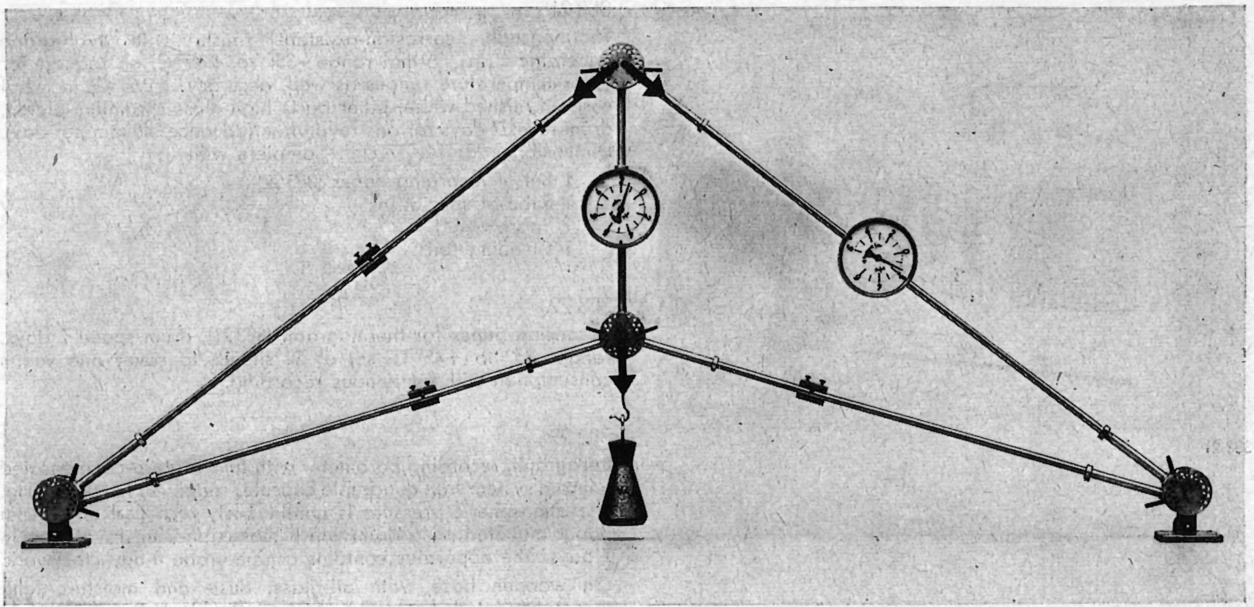


Fig. 128 PH 2078

The following table contains a list of the contents of each set. A short description of the individual part follows.

Contents of the **Basics set** and the **Experimenting Set:**

Cat. No.	Name of part	Basic Set	Exp. Set
343 65	Tension and Compression gauge	1	2
343 66	Hook	1	1
343 67	Rod, 13 cm long	2	2
343 68	Rod, 21.5 cm long	2	4
343 69	Rod, 30 cm long	2	4
343 70	Rod, 38.5 cm long	2	4
343 73	Support	2	2
343 74	Coupling	3	8
343 75	Multiple junction	1	2
343 76	Boss	2	5
343 77	Arrow	2	4
343 78	Wrench	1	1
343 85	Storage box	1	1

Description of the individual parts, which are available to supplement the sets, or as spares:

343 65

Tension and compression gauge, for connection into trusses to measure tensile and compression forces. The scale, dia. 100 mm, is rotatable and tensile and compression forces ranging from 0 to 6 kp (kg wt) can be measured. The directions of the forces are marked by symbols. Accuracy of reading: 100 p (g wt).

343 66

Hook, for attaching weights.

343 67

Rod, 13 cm long, dia. 10 mm, high gloss chromium-plated steel.

343 68

Rod, 21.5 cm long, dia. 10 mm, high gloss chromium-plated steel.

343 69

Rod, 30 cm long, dia. 10 mm, high gloss chromium-plated steel.

343 70

Rod, 38.5 cm long, dia. 10 mm, high gloss chromium-plated steel.

343 73

Support, to fasten the assembly to the workbench by means of a clamping screw. A pair of plates with approx. 30 holes enables structures to be continued any desired direction.

343 74

Couplings, to make joints between rods and multiple junctions or supports, these joints being rotatable.

343 75

Multiple junction, to join several rods meeting from different directions.

343 76

Boss, to join two rods. Can be replaced by a tension and compression gauge for measurement.

343 77

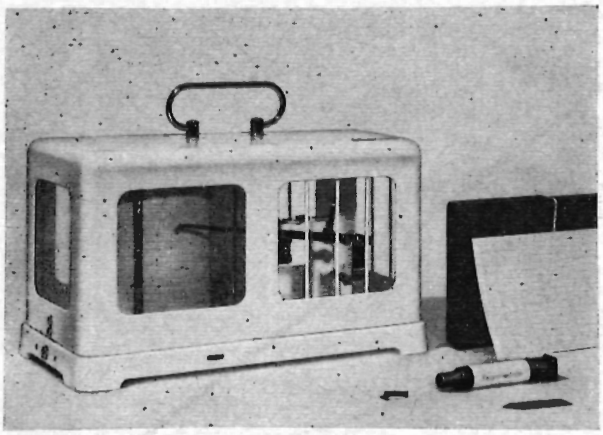
Arrow. The red arrow provided with a magnet can be stuck on at any desired point of the structure, e.g. to a multiple junction or support, to indicate the direction of the force vector.

343 78

Wrench, to fasten rods in bosses, couplings, junctions or tension and compression gauges.

343 85

Storage box, to store the individual parts of the set, the available storage space being kept so large that in addition to the experimenting set (343 61) further parts and 2 more gauges (that is, 4 in all) can be accommodated.



383 21

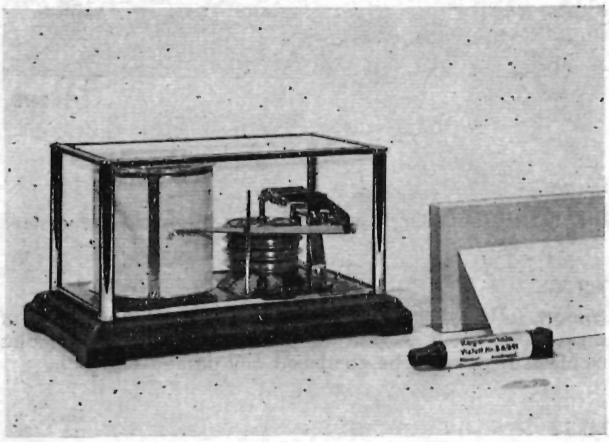
383 21

Thermograph, corrosion-resistant finish, with high-grade bimetallic strip; normal range –35° to +45° C, on request for other temperature ranges as well, accuracy: ±0.2° C; in metal case, varnished white, other parts high-gloss chromium-plated, drum takes 7 days for one revolution (advance: 40 mm per day). Dimensions: 28×14×17 cm^3. Complete with

1 Set of recording paper (383 22)
1 Tube of special ink
1 Spare pen*)
1 Cleaning foil

383 22

Recording paper for thermograph (383 21), drum speed 7 days, range –35° to +45° C; set of 54 sheets, to cover one year's consumption with continuous recording.



383 29

383 29

Barograph, recording barometer with temperature-compensated aneroid system with quadruple capsule; range 720 to 800 mm Hg. The atmospheric pressure is continuously recorded on special paper mounted on a drum which makes one full revolution in 7 days. The apparatus contains a high-grade 8-day clockwork.

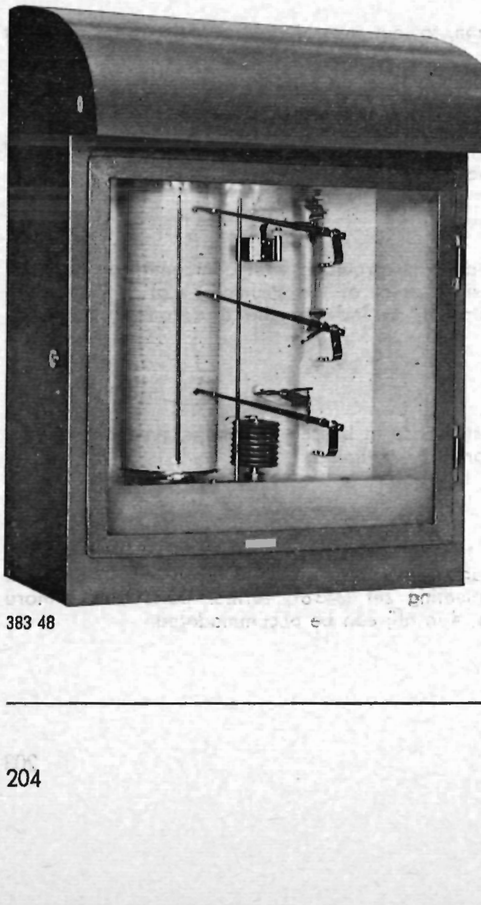
On wooden base, with all-glass, dust- and moisture-tight, chromium-plated protective cover, 21×12×11.5 cm^3, weight 1.3 kp (kg wt). Complete with:

1 Set of recording paper (383 30)
1 Tube of special ink

383 30

Recording paper for barograph (383 29); set of 55 sheets, to cover one year's consumption with continuous operation.

Size of sheets: 235×69 mm^2, recording height 64 mm, with 2-hour graduations.



383 48

383 48

Meteorograph – Combined recording instrument

Combines barograph, thermograph, and hygrograph in one compact unit. Atmospheric pressure, temperature and relative humidity are recorded on one single diagram. In corrosion-resistant, weatherproof finish; on swivel support in a well-aired metal case, outside: grey hammer finish, inside: white varnish, dimensions: 55×40×28 cm^3, suitable for mounting on an outdoor wall; with safety lock and key.

The meteorograph covers the standard ranges:

Barograph: 710 to 790 mm Hg (or can be adjusted to any other atmospheric pressure range depending on the height above sea level at which the apparatus is to be used)
Thermograph: –35 to +40° C
Hygrograph: 0 to 100% relative humidity

Drum speed: 7 days (advance: 40 mm per day).
Complete with: 1 Set of recording paper (383 49), 1 tube of special ink, one piece of cleaning foil, 3 spare pens, 2 safety lock keys.

Please state height above sea level when placing an order.

383 49

Recording paper for meteorograph (383 48), for the 3 standard ranges:

Atmospheric pressure: 710 to 790 mm Hg (can also be supplied with neutral 80-division pressure range)
Temperature: –35° to +40° C
Relative humidity: 0 to 100%.

One set of 55 sheets to cover one year's consumption with continuous operation.

383 55

Indoor weather observation unit. Combined barometer, thermometer and hygrometer; wall unit on bright varnished oakwood base, size 56×20 cm², instruments in chromium-plated cases with aluminium dials, dia. 130 mm, particularly clearly legible.

Ranges:

Barometer:	Double scale, 730 to 790 mm Hg and 975 to 1,050 mb
Thermometer:	–25 to +55° C
Hygrometer:	0 to 100% relative humidity

383 56

Outdoor weather observation unit: Barometer, thermometer and hygrometer on grey hammer-finish metal plate to be mounted on a wall, size 54×19 cm². High-precision gauges, e.g.

Barometer mechanism with corrosion-inhibited parts, running on jewelled bearings and adjusted according to official standards;

Hygrometer provided with durable plastic thread mechanism;

each instrument in weather-proof, eloxadised aluminium case with clear, large scale of 160 mm dia.

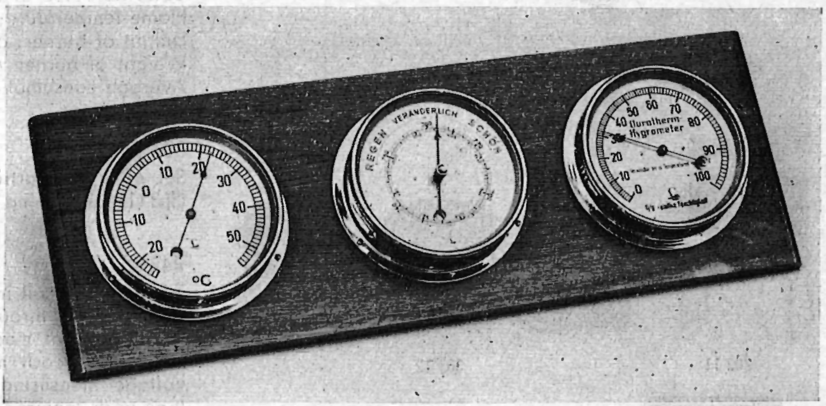
Ranges:

Barometer:	Double scale, 680 to 795 mm Hg and 910 to 1,060 mb
Thermometer:	–30° to +60° C
Hygrometer:	0 to 100% relative humidity

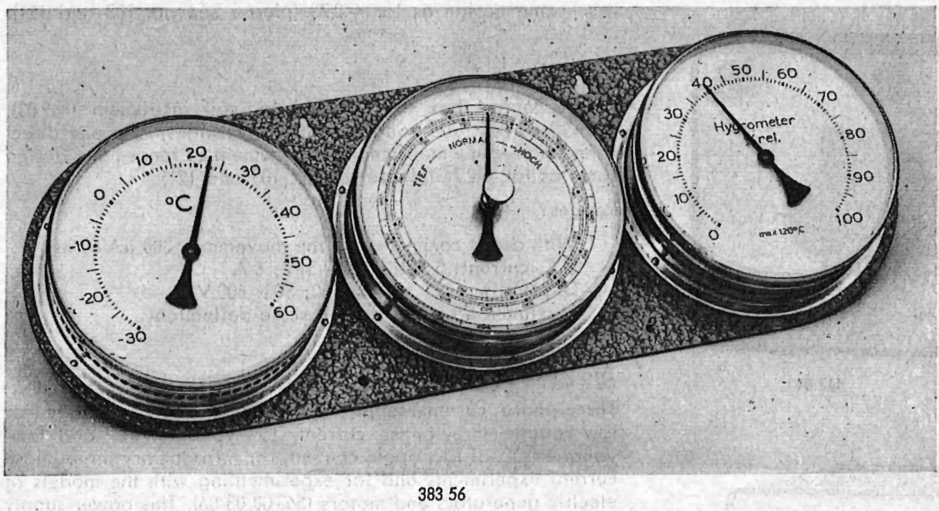
Complete with key for adjusting reference barometer pointer.

Regenmes
nach
Prof. Hellman

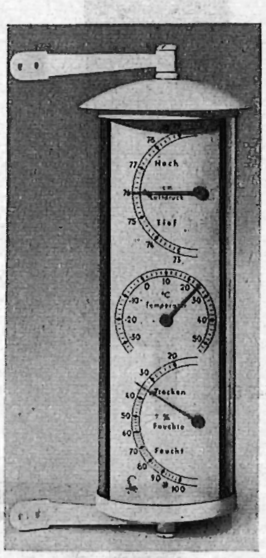
383 45 383 44



383 55



383 56



383 57

383 44

Rain gauge according to Hellmann; collecting vessel and base of sheet zinc, ivory-varnished; height approx. 31 cm, dia. approx. 12 cm. Collecting surface 100 cm²; collecting surface limited by a turned brass ring with sharp edge.

Complete with rain gauge cylinder of glass, height approx. 18 cm, dia. approx. 60 mm, with etched graduation from 0 to 25 mm of rainfall, with 1 mm divisions, and holder for mounting rain gauge on a pole.

383 45

Spare measuring glass for rain gauge (383 44).

383 57

Window weather observation unit, barometer, thermometer and hygrometer. This combination is particularly well protected against external influences. It can be arranged outdoors, preferably on the outer window frame, and makes for convenient reading from within the room. The movements are scaled against weather effects and other interferences, such as insects, dust, dampness, etc.

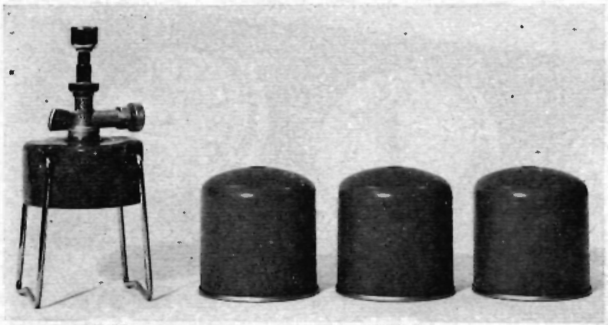
Dimensions: 18 cm high, dia. 50 mm, scale plate: 14×14 cm², with 2 holders and wood screws. Ranges: Barometer 730 to 790 mm Hg, thermometer –30° to +50° C, hygrometer 20 to 100% relative humidity.

300 75

300 75

Laboratory stand, made of metal, eloxadised; with stable, non-slip bottom surface, 18×26 cm²; height continuously variable between 7 and 25 cm.

This very rigid stand is suitable for setting up indicating or demonstration apparatus which is to stand out above the rest of the assembly, and for continuous adjustment of height of individual pieces of apparatus within the experimental arrangement.



303 11 303 12

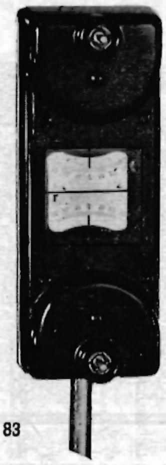
303 11

Bunsen burner for butane gas, for schools and laboratories, light, independent of hose connections and gas pipes, economical, with adjustable flame; for use with the set of 3 gas cartridges (303 12).

Calorific value of the flames: approx. 650 kcal/h
Flame temperature: 1,100° C
Height of burner: approx. 19 cm
Weight of burner with cartridge: approx. 590 g
Average consumption at 20° C: 60 g/h

303 12

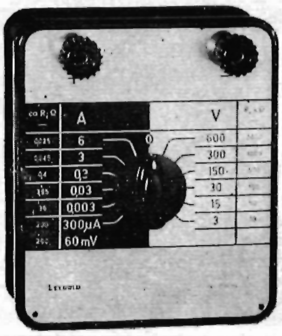
Set of 3 gas cartridges, for use with the butane gas burner (303 11), containing 200 g each.



442 83

442 83

Twin moving-coil instrument, centre zero; scale divisions ranging from –30 through 0 to +30 on each scale. For extending the number of measuring ranges, either a range control box (442 84) for each movement, which has 13 D.C. current and voltage measuring ranges, or a range control box (442 74) (one each required per movement) having 24 measuring ranges for D.C. and A.C. current and voltage, should be used. Otherwise same design as for 442 73 (please see pp. 103 and 121).



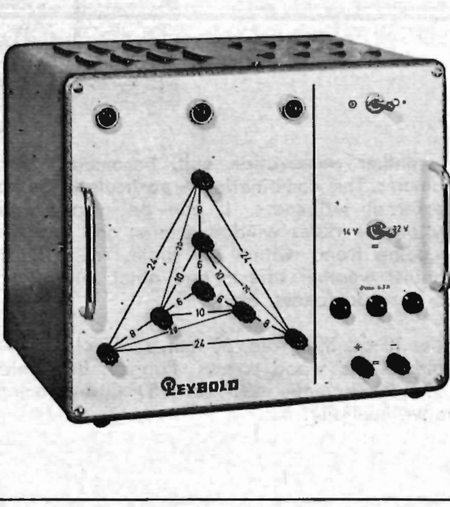
442 84

442 84

Range control box for twin moving-coil instrument (442 83), with 13 current and voltage measuring ranges, with one direct connection to the movement. Arrangement of ranges and design same as for 442 74 (please see pp. 103 and 121).

Ranges:

With direct connection to the movement: 300 µA/60 mV
D.C. current: 0.003; 0.03; 0.3; 3; 6 A
D.C. voltage: 3; 15; 30; 150; 300; 600 V
Maximum error: 1% of full scale deflection



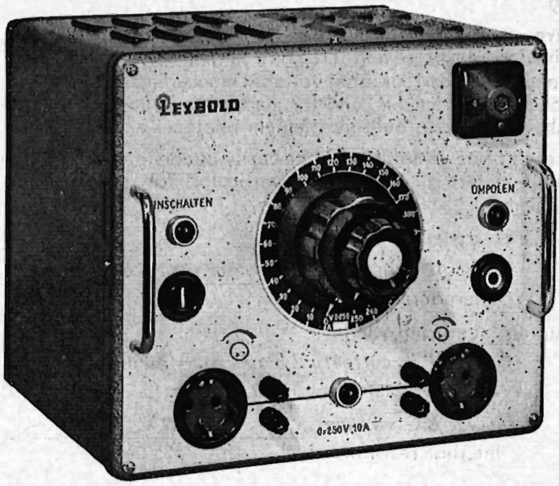
522 48

522 48

Three-phase current supply. Powerful source of voltage for low-voltage three-phase current, low-voltage A.C. and low-voltage D.C. of low ripple content, for introductory three-phase current experiments and for experimenting with the models of electric generators and motors (563 00/03/06). This power supply yields two interlinked three-phase voltages with common centre and, through a built-in three-phase bridge switch, which can be switched to either of the two three-phase voltages, a D.C. voltage. Moreover, A.C.'s of different voltage can be tapped off between any two terminals of the two interlinked three-phase currents. All voltages that can be derived from the unit can be loaded up to a maximum of 10 A, provided the total power output does not exceed 420 W.

Technical data:

AC.: 3×6/8/10/14/20/24 V, max. 10 A
D.C.: 14 or 32 V, max. 10 A, residual ripple content 4.2%
Total power output: 420 W
Casing dimensions: 31×27×25 cm³
Weight: 21 kp (kg wt)



522 45

522 45

Rotary variable transformer, ring-core auto-transformer with two independently variable output tappings of 0 to 250 V, total maximum load 2.5 kW; for connection to 220 V, 50 c/s (or 250 V on special request).

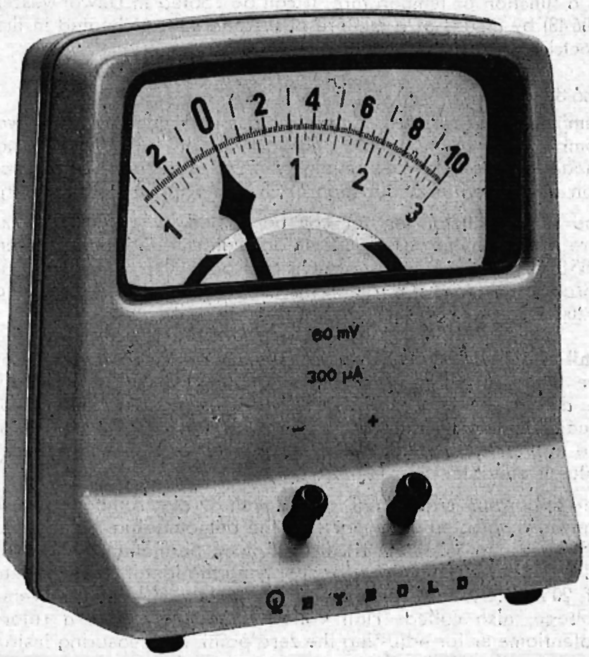
The maximum available current of 10 A can be shared between the two outputs in any desired proportion. Each output is provided with a socket for a mains cable and with a pair of screw terminals and 4 mm sockets for taking off the desired voltage.

The mains lead connected to the primary circuit of the rotary variable transformer must be plugged into a supply socket in such a manner that the neutral leads of the outputs are connected to the neutral side of the mains supply. Two indicator lamps indicate whether this condition is satisfied or not. The outputs are then only connected into circuit after the built-in circuit breaker is closed by pressing a special push-button; the circuit breaker can be opened again by means of a second push-button. The electromagnetic and thermal cut-out, which is also built into the apparatus, opens the circuit breaker in case of overload or short-circuit.

Operation of the rotary variable transformer from A.C. mains both of whose A.C. leads are live (3-phase supplies: 3×220 V, or 3×250 V) is not recommended. The commonest type of 3-phase supply (3×220/380 V, or 3×250/432 V) delivers A.C. with one live and one neutral lead, and is therefore best suited to the operation of the rotary variable transformer.

Technical data:

Alternating output potentials: 2×0-250 V
Maximum total current: 10 A
Case dimensions: approx. 31×27×25 cm^3
Weight: approx. 18 kp (kg wt)
Input: 220 V, 50 c/s
(or 250 V, 50 c/s on special request)



531 87

531 87

Demonstration millivolt-microammeter, same design as for 531 86 (please see p. 120), but only with the two measuring ranges resulting from direct connection to the movement.

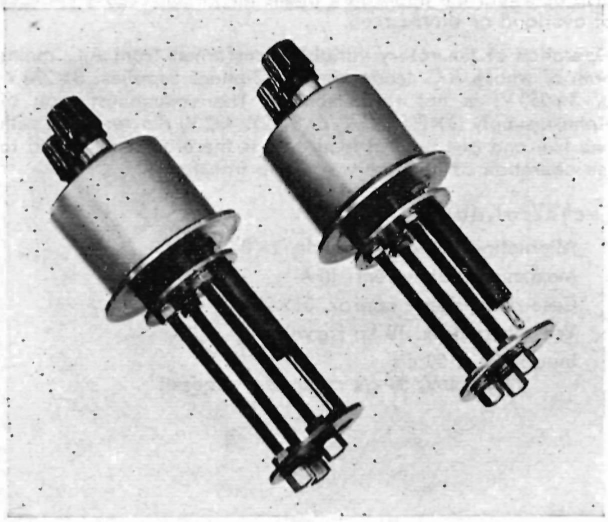
The apparatus can be used together with the measuring amplifier (532 01) or used wherever a highly sensitive measuring instrument for small voltages or small currents is needed. It may, for example, be used with the thermocouple (557 01), with the selenium photocell (558 11) or with the photodiode in case (558 12) and as a zero instrument for the measuring bridges (536 02 or 536 03).

Technical data:

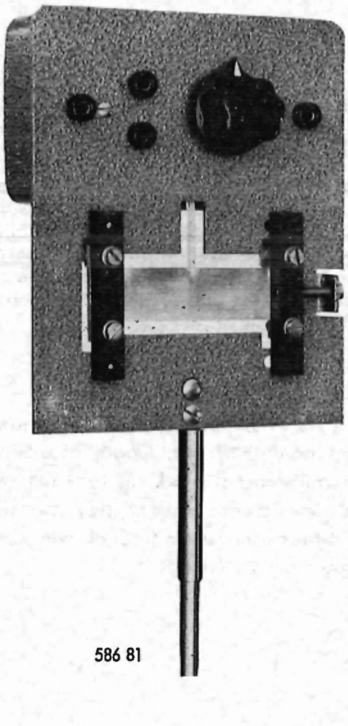
Full scale deflection: 300 µA or 60 mV
Maximum error: 1.5% of full scale deflection
Scale: Zero point half left, length of scale arc approx. 20 cm, two calibrations: black –30 to +100, red –10 to +30
Casing: 30×30×16 cm^3, of light grey, percussion-resistant plastic, dust-proof, antistatic treated, with rubber feet.
Weight: approx. 3 kp (kg wt).

mA
A
V
1,8
6
60
0,6
6
600
60
6
Lux

531 59



586 80 586 82



586 81

531 59

Metravo multi-meter. This handy, pocket-size multi-meter, contained in plastic casing, 116×85×38 mm³ in size, serves for D.C. and. A.C. current and voltage measurements, for line-resistance measurements, and for measuring illumination intensities by means of a built-in selenium photocell.

As a result of its versatility and its easily understandable design the multi-meter is suitable in particular for students' experiments.

Technical data:

Full scale deflection:	180 µA (at 60 mV)
Internal resistance:	333 Ω
Further measuring ranges:	
D.C. or A.C. current:	1.8 mA, 6 mA, 60 mA, 0.6 A, 6 A
Internal resistance:	110 Ω, 80 Ω, 10 Ω, 1 Ω, 0.1 Ω
D.C. or A.C. voltage:	6 V, 60 V, 600 V
Internal resistance:	555 ΩV

Scales: logarithmic, with mirror to eliminate parallax errors; 55 mm long

Ohm scale:	∞ - 10,000 - 1,000 - 0 Ω
Intensity of illumination (D.C. scale):	0–600 lux
Max. error at any point on the scale:	1% of f.s.d.
Frequency errors:	25–5,000 c/s = ±1% 15–25, and 5,000-10,000 c/s = ±2%

586 80

Noble-metal resistor, on ceramic former, with two combined screw terminals and sockets to take 4 mm plugs or spade terminals, covered with perforated sheet metal to protect it against mechanical damage; dia. approx. 3.5 cm, approx. 16 cm long.

The noble-metal resistor can be used to determine Ohm's law as a function of temperature. It can be cooled in Dewar vessel (386 48) by means of a mixture of ice and salt, or heated in the electric oven (555 81/82).

586 82

Semiconductor resistor, sealed in glass and mounted, with two combined screw terminals and sockets for 4 mm plugs and spade terminals, for determining the D.C. resistance as a function of temperature; dia. approx. 3.5 cm, approx. 12 cm long.

The semiconductor resistor can be cooled by a cooling mixture in the Dewar vessel (386 48) or heated in the electric oven (555 81/82). Its D.C. resistance is approx. 200 Ω at room temperature; it varies approx. in the ratio $10^4:1$ between –70° and +200° C.

Hall effect apparatus, silver. For a more profound treatment of the processes of electric conduction in solids it is necessary to discuss the Hall effect which represents one method of measuring the number and sign of electric charge carriers in the interior of a solid. For this purpose the Hall effect apparatus is suitable.

The apparatus is designed for use with an electromagnet which can be assembled from parts of the demountable transformer (562 11/12 and 562 13/560 31). It contains a permanently mounted silver ribbon, connections for supplying the longitudinal current of 20 A D.C., and connections for taking off the transverse voltage, also called "Hall voltage", complete with a rotary potentiometer for adjusting the zero point. As measuring instrument for the Hall voltage, we recommend the school mirror galvanometer (532 10), which should be highly damped to increase its voltage sensitivity.

The Hall voltage that can be obtained is of the order of a few microvolts.

586 81

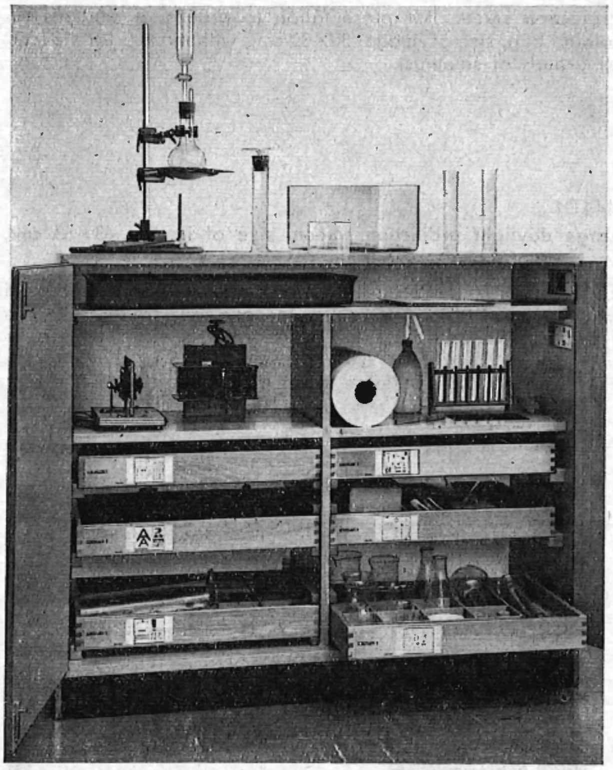
Hall effect apparatus, silver. Consists of a silver ribbon, approx. 0.05 mm thick, 20 mm wide, 65 mm long, mounted on an aluminium plate, approx. 13×15 cm², on a stand rod, dia. 0.8 cm, approx. 12 cm long. As source of D.C. for the longitudinal current, the 2 V winding of the coil with 46 turns (562 18) of the demountable transformer, together with rectifier (523 72), should be used.

quik-stick
spray-on
adhesive
fast—easy to use

309 78

309 78

Quik-stick, spray-on adhesive, fast – easy to use – will stick paper to all smooth surfaces, can be removed and replaced like tape. In can, approx. 340 g net wt.



601 90 with cabinet (602 00)

601 90

Collection of chemistry apparatus "GSC". Supplementary to the collection of physics apparatus "GS" (598 30, please see p. 200). This collection comprises approx. 50 different pieces of apparatus for performing basic experiments in chemistry.

The collection can be conveniently stored in the cabinet (602 00).

For details and a list of the apparatus contained in the collection, please see our list GSC, which we shall be pleased to send you on request.

602 00

Cabinet for the collection of chemistry apparatus "GSC", storage cabinet for convenient storage of the collection of chemistry apparatus GSC (601 90) and those pieces of apparatus from the collection GS (598 30) that are needed for chemistry experiments.

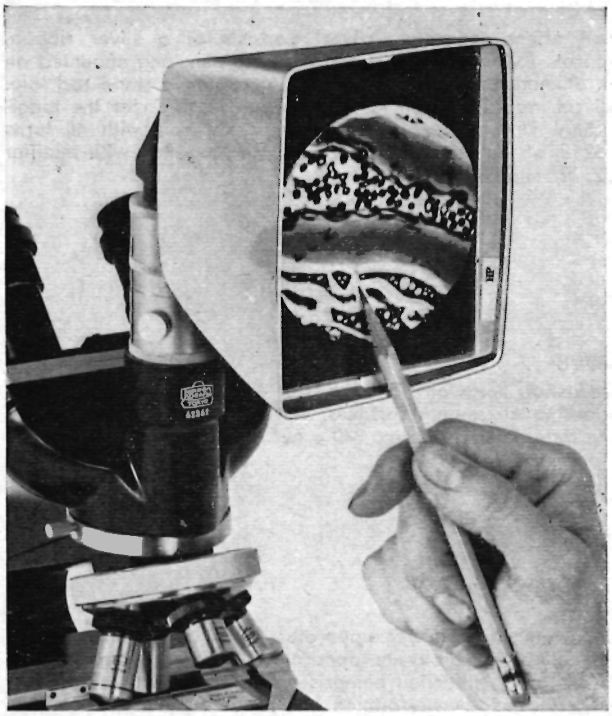
The cabinet is 1.20 m wide, 0.50 m deep and 1.00 m high. It contains 6 portable drawers, each subdivided into compartments, and 3 permanently fixed shelves. The places for keeping the different pieces of apparatus are marked with plates showing illustrations of the equipment.

The cabinet rests on a base. The upper cover plate is provided with a plastic cover that is resistant to chemical agents.

442 28

Microscope screen, for group viewing of specimen material under the microscope in normal room light.

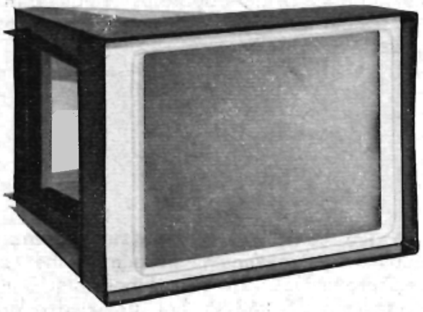
Viewing screen: 9×12 cm², made of nonbreakable plastic; grainless projection surface, with no halation effect. Eloxadised housing; weight 250 g, in case. Includes 3 adaptors for fitting to any standard microscope, e.g. 442 10/13/14 (please see p. 80).



442 28 PH 2091

444 32

Projection screen, for desk-top presentation, size of image: 13.5×17.5 cm²; for one or two spectators.



444 32

444 33

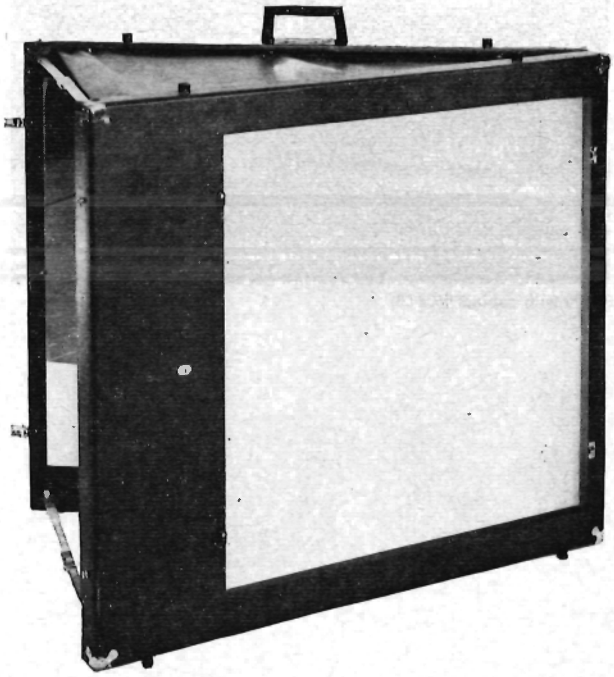
Projection screen, for presentation to groups of students; in folding bag, size of image: 30×30 cm², with mirror; for viewing by groups of students.

444 33 PH 2088

444 34

Large daylight projection screen, size of image: 63×63 cm², for presentation to whole classes.

The projection screens (444 32/33/34) are suitable for daylight projection of films and slides. In rooms where black-out is feasible, however, other projection screens may likewise be used, e.g. Planoflex, 100×100 cm² (441 55), or Linomat, 130×130 cm² (441 57). Please see p. 79.



444 34

List of literature and printed matter

The physics apparatus listed in this catalogue is described in many places in the literature of the experimental technique of physics.

In well-known textbooks of experimental physics, too, many experimental directions are given which are of great use in conjunction with our apparatus.

In addition, however, we issue a great variety of publications, for instance our quarterly House Magazine, individual books, articles in specialised journals, directions for use, physics leaflets and special pamphlets in which we give additional particulars of our apparatus, their mode of action and their use in physics experiments. These publications are, for convenience, summarised in the next few pages.

LEYBOLD Physics Leaflets

We are continually issuing LEYBOLD Physics Leaflets describing the preparation and performance of experiments with Leybold equipment.

These contain detailed theoretical, practical and historical information, the necessary formulae and illustrations. On the front side of each leaflet, the experiment itself is described. The rear contains a list of the apparatus required, a representation of the most suitable assembly, circuit diagrams, notes about the experimental technique and photographs of arrangements that have been found suitable.

LEYBOLD Physics Leaflets are arranged according to the international system of decimal classification. In this system, physics forms part of Division 5, "Mathematics and Natural Sciences"; within the totality of these sciences, part 53 refers to Physics proper.

So far, 4 series of leaflets have come out.

The leaflets published to date treat in detail a number of subfields of physics. Thus, for example, from the field of mechanics, the laws of dynamics as demonstrated with Fletcher's trolley and the large electric stop-clock; from the field of oscillations, experiments with the wave trough and the torsion apparatus for studying waves; from the field of optics, a considerable number of experiments; from the field of electricity, a number of experiments with the school cathode ray oscilloscope and with the transmitter and receiver for centimetre waves.

The last two series also contain a number of leaflets from the field of atomic and nuclear physics.

Most of the experiments described in the leaflets are equally suitable as classroom demonstration experiments and for practical class-work or study group work.

LEYBOLD Physics Leaflets
Instructions for, and background to, experiments with LEYBOLD equipment in physics teaching. Printed on chamois cardboard with filing holes on one side. These descriptions of experiments are arranged according to the international system of decimal classification and can be supplied only in complete series.

599 21
1st series, 72 sheets with preface and introduction, in file, with divider cards.

599 22
2nd series, 52 sheets with list of contents

599 23
3rd series, 49 sheets with list of contents

599 24
4th series, 50 sheets, in file, with divider cards, 2 complete lists of contents and notes on how to arrange the sheets in two files.

599 00
File for LEYBOLD Physics Leaflets.

Our prospectus HB 4 lists the experiments described in our Physics Leaflets. Please note that the separate series do not correspond to different parts of the subject, but to the order of publication.

Manuals of experiments (VA-manuals)

For experiments of a simpler type in the lower and middle stages of secondary schools, etc., both for practical work and for demonstrations, we have issued manuals with descriptions of experiments. In these we describe experiments which can be performed with the apparatus termed "Collections of apparatus" by us. The manuals each cover a separate field of physics and contain a list of the apparatus required for the experiments described in them.

599 121
No. 1, **Mechanics,** with the description of 41 experiments and some general notes

599 122
No. 2, **Vacuum Physics,** with a description of the most important apparatus, and 15 experimental instructions

599 123
No. 3, **Heat,** with descriptions of 32 experiments

599 124
No. 4, **Oscillations,** with descriptions of 20 experiments

599 125
No. 5, **Optics,** with general notes and with descriptions of 34 optical experiments

599 126
No. 6, **Electricity and Magnetism,** with descriptions of the equipment and instructions for 39 simple experiments

599 127
No. 7, **Electrical Machines,** with a description and 14 experimental arrangements.

598 032
Manual: **Practical work in schools,** suggestions for practical class-work experiments with LEYBOLD equipment from the special cabinet with six identical sets of apparatus (598 01/04). 44 Experiments from the fields of: mechanics, heat, optics and electricity; 36 pages, 50 illustrations.

Experiment cards for practical work in schools are being prepared.

Books with description of apparatus and experiments

388 15

Paper by Schürholz, **"Gerät zur Messung des Arbeitswertes der Wärmeeinheit"**, in German, detailed description and directions for the mechanical equivalent of heat apparatus (388 14). For detailed instruction beyond the scope of the Directions for Use. 21 pages, 8 illustrations.

411 00

Book: Dr. H. Kröncke, **"Mechanische Schwingungen und Schall"**, in German, detailed descriptions of experiments and experimental instructions for our apparatus. For detailed information beyond the scope of the ordinary Directions for Use. 2nd improved edn, 147 pages, 127 illustrations, cardboard back.

532 042

Book: Dr. H. Kröncke, **"Optische Versuche mit Aufbauteilen"**, in German. This book, which is already in its third edition, contains detailed descriptions of our optics equipment and detailed instructions for approx. 100 experiments. For detailed information beyond the scope of the ordinary Directions for Use. 120 pages, 132 illustrations, soft back.

546 462

Pamphlet: H. Schlechtingen, **"The Measuring Amplifier and its Uses"**, in English, suggesting applications of LEYBOLD equipment, 2nd enlarged edition (at present in preparation).

562 40

Book: Th. Wulf, **"The Wulf electroscope"**, 4th edn (edited by Dr. Kröncke), English translation, with detailed description of the instrument and of approx. 90 experiments that can be performed with it. For detailed information beyond the scope of the normal Directions for Use. 110 pages, 43 illustrations, soft back.

575 16

Book: Stud.-Rat J. Friedrich and Dr. H. Kröncke, **"Der zerlegbare Transformator"**, in German. Detailed description of the demountable demonstration transformer and the accessories available for it, and of more than 80 experiments that can be performed with it; for detailed information beyond the scope of Directions for Use; 2nd improved edition, 194 pages, 159 illustrations, cardboard back.

599 90

Pamphlet: H. W. Ernst, **"Versuche mit dem Schul-Kathodenstrahl-Oszillographen"**, in German, 140 descriptions of experiments with numerous illustrations, soft back.

The House Magazine "Die LEYBOLD-Welle"

Our quarterly House Magazine, available in English, is printed for all those interested in physics, and in particular, those interested in physics teaching.

It appears every three months. Each number contains papers about Leybold apparatus and experimental arrangements that have been found suitable by experience. These articles occasionally also treat subjects of a more general nature relating to physics teaching at home and abroad. But above all, suggestions for new experiments and their performance with LEYBOLD equipment are described, in this way introducing, at the same time, any new apparatus developed by us.

Under the heading "We turn back the pages", each issue contains a reprint of an original paper from the history of physics. Often it is very difficult to obtain the original papers on many classical developments in physics. Therefore we try, in our House Magazine, to publish excerpts from old sources which may be stimulating and useful in teaching.

Under the heading "Leybold news" we report on our participation in meetings of teachers' associations and exhibitions at home and abroad, on foreign visitors to our firm, on the physics courses in Cologne and in our branches and on other events in our physics department.

Please write to us if you should like to read our House Magazine regularly.

Directions for Use

Directions for Use are issued for most of our apparatus, in addition to the simple operating instructions, and are supplied free of charge with the apparatus. The collection is constantly being extended. These Directions for Use contain a detailed description and all necessary technical data, describe suitable assemblies, including setting-up, adjustment, and initial operation of the apparatus. Numerous illustrations, circuit diagrams and suggestions for the experimental arrangements illustrate the use of our apparatus. Upon request, these Directions for Use can be sent on approval, or to replace lost Directions for Use.

599 90

File for Directions for Use

for collecting and filing our Directions for Use, which are arranged according to catalogue numbers, we supply a strong file (plastic cover) with lever clip, of the size of commercial file covers. This file will take about 200 cards and is highly recommended for careful storage and easy finding of the Directions for Use.

Sectional catalogues descriptive leaflets

PH 41 E	**The Wulf electroscope**
PH 44 E	**Electronic Units** (Electronics Demonstration Sets I–III)
PH 44 E-1a	**Electronic Units** (Electronics Demonstration Set IV)
PH 45 E-2	**Generator and electric motors models**
PH 46 E	**RC-oscillator**
PH 48-2	**"Structure"**, crystal lattice models
PH 49 E	**Optical equipment** for school experiments
PH 60 E	**Twin moving-coil instrument**, for projection
PH 65 E	**Basic Physics Kit** (BPK), Catalogue
PH 70 E	**Atom models**
PH 75 E	**Basic Physics Kit** (BPK), Introduction

Bulletins

Descriptions of all the experiments that can be performed with particular pieces of LEYBOLD apparatus.

11 E	**The photocell: Determination of Planck's constant**
14 E	**Rotating mirror for determining the velocity of light**
23 E	**LEYBOLD'S fine-beam tube** (gas-focussed cathode ray tube)
24 E	**The Franck-Hertz experiment**
25 E	**Torsion balance**
26 E	**Gas discharge lamps**
27 E	**Fletcher's trolley**
28 E	**Van de Graaff generator**
29 E	**The wave trough**

Further bulletins will follow.

Other written matter

Manual (Directions for Use):
Experiments with the Electronic Units
(Electronics Demonstration Sets I–III)

Manual (Directions for Use):
Experiments with the Demonstration Scaler

Manual (Directions for Use):
Oscillation experiments

A list of contributions published in our House Magazine "Die LEYBOLD-Welle"

Manuals: **"Suggestions for classroom experiments with X-ray and discharge tubes",**
"Suggestions for classroom experiments with radioactive sources",
"Suggestions for classroom experiments with the shielded laboratory source of neutrons",
"School Health Physics".

Detailed compilation of all notes on experimenting with X-ray and discharge tubes, radioactive sources and the shielded laboratory source of neutrons, with introduction, further interesting data, and many illustrations.

Special publications:

Atom models for schools (Directions for Use)
The field emission electron microscope (FEM 4 E)
A Demountable Transformer, by Dr. K. Hecht
Index of LEYBOLD's Physics Leaflets (PH L 1)

PLATE I

(between pages 40 and 41)

Lift and drag on aerofoils in the blast of the blower are measured with the two-component balance.

The arrangement shown in the illustration contains the following apparatus:

Blower, 220 V or 110 V	373 19/24
Two-component balance	373 30
Torsion spring balance	373 32
Set of aerofoils	374 12

PLATE II

(between pages 48 and 49)

The glass sphere of the baroscope experiences a buoyant force in air which decreases as the pressure under the bell jar drops. The ball sinks down.

The arrangement shown in the illustration contains the following apparatus:

Gas ballast pump D 2 with A.C. motor	110 12 S
Vacuum chamber, consisting of	
Base plate	378 11
Rubber disc	378 36
Glass bell jar	378 56
Baroscope	379 10
Short manometer	379 05

PLATE III

(between pages 56 and 57)

The electrical equivalent of heat and the specific heats of solids are determined in the same Dewar vessel using different tops.

The arrangement shown in the figure contains the following pieces of apparatus:

Left part:	
Low-tension power supply	522 38
Universal moving-coil instrument, zero on the left	531 55
Electric calorimeter attachment to determine the electro-mechanical equivalent of heat	384 20
with	
Dewar vessel with base	386 48
Connecting leads	
Right part:	
Dewar vessel calorimeter	384 16
Heating apparatus	384 34
Water separator	384 17
Stands	
Rubber tubing for supplying steam	

PLATE IV

(between pages 72 and 73)

A small speaker and the RC-oscillator are used to excite longitudinal oscillations in an air column in Kundt's tube. The standing waves are rendered visible by means of cork dust.

The arrangement shown in the figure contains the following pieces of apparatus:

Kundt's tube	413 01
Small speaker	580 06
RC-oscillator	587 00
Cardboard matching funnel (see Directions for Use for Kundt's tube 413 01)	
Lamp house	450 60
Lamp, 6 V, 30 W	450 51
Single-lens condenser with sliding aperture selector	460 17
Transformer, 6 V, 30 W	562 76
Connecting leads	
Stands	

PLATE V

(opposite p. 80)

School microscope (442 10)

Case for school microscope (442 11)

Student microscope (442 13) with accessories and case, and attachable mechanical stage (442 15)

PLATE VI

(opposite p. 81)

Dry dark field substage condenser (442 16) with accessories and case

Oil immersion dark field substage condenser (442 17) with accessories and case

Teacher's microscope (442 14) with accessories and case

PLATE VII

(between pages 96 and 97)

Transparent models made of highly photoelastic polyester resin are elastically deformed and observed in circularly polarised light. The lines of equal mechanical stress, the so-called isochromatics, are rendered visible in projection by means of the double refraction produced.

The arrangement shown in the figure contains the following pieces of apparatus:

Arc lamp with double-lens condenser	442 32
Base for arc lamp	442 44
Automatic feed accessory for arc lamp, for 220 to 240 V, 50 c/s	442 33
Ballast resistor, 220 V, 10 A (not visible)	442 37
Small optical bench with short side holder	460 43
Prism table	460 25
Plate glass box, 100×80×25 mm³, filled with water, as heat filter	477 25
2 Lenses in frame, dia. 75 mm, f = 150 mm	460 08
Lens in frame, dia. 40 mm, f = 200 mm	460 04
Pair of polarising filters, in frame	472 40
Pair of quarter-wave plates, in frame	472 60
Set of photoelastic models	471 95
Leybold bosses as saddle bases	301 01
Weight with hook, 5 kg	388 24
Fishing line	309 49
Projection screen	441 55/57

PLATE VIII

(between pages 104 and 105)

The vertically directed field of a circular magnet and a radially directed electric field produce a circular motion of the electrolyte due to ionic friction.

The arrangement shown in the figure contains the following pieces of apparatus:

Leitz projector "pradovit"	442 91/93
Holder for attachments	442 95
Vertical attachment	442 57
Horizontal attachment	442 58
Equipment for demonstrating ionic friction	442 75
Flat glass dish, round	442 68
Low-tension power supply	522 38
Copper sulphate solution	
Connecting leads	

PLATE IX

(between pages 160 and 161)

Lissajous figures are formed on the oscilloscope screen by the superposition of two sinusoidal alternating voltages, of which one, of mains frequency, is derived from the demountable demonstration transformer and the other, of variable frequency, from the RC-oscillator.

The arrangement shown in the figure contains the following pieces of apparatus:

School cathode ray oscilloscope	575 15
RC-oscillator	587 00
Demountable demonstration transformer, consisting of U-core with yoke	562 11
Clamping device	562 12
Coil with 1,000 turns (at 220 V mains voltage)	562 15
or: Coil with 500 turns (at 110 V mains voltage)	562 14
Coil with 250 turns	562 13
Recommended for postacceleration:	
High-tension power supply	522 37

PLATE X

(between pages 168 and 169)

Model of a DNS molecule, made up from the atom models designed by Stuart und Briegleb (see also pages 194 and 196). Desoxyribonucleic acid is a constituent of cellular nuclei. The genes, in particular, consist of this compound.

PLATE XI

(opposite p. 200)

Basic Set GS, set of apparatus II, with cupboard (598 31)

Basic Physics Kit (BPK) for primary, preparatory, and all types of secondary schools:

One set of practical work equipment (591 90) with supplementary parts in case (591 91)

Four sets of practical work equipment (4×591 90) with supplementary parts in cabinet "Organisat" (591 94).

PLATE XII

(opposite p. 201)

Two-piece cabinet with 6 sets of apparatus for practical work (598 01).

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E. LEYBOLD'S NACHFOLGER · 5 KÖLN-BAYENTAL · GERMANY
BONNER STRASSE 504 · ✉ 195 · ☎ KÖLN [0221] 20561 · ⌨ 08882815 · ⚡ LEYBOLDVAK KÖLN

Printed in Germany · 30–11–64 DKD

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